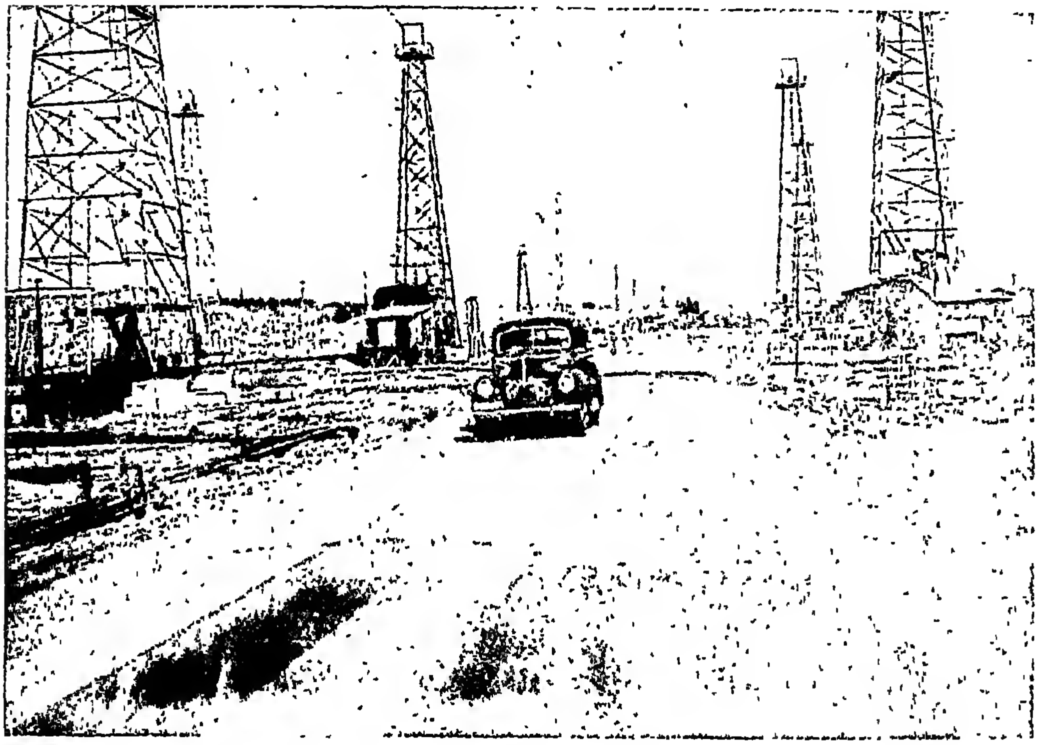
See Pages (vi) and (ix).

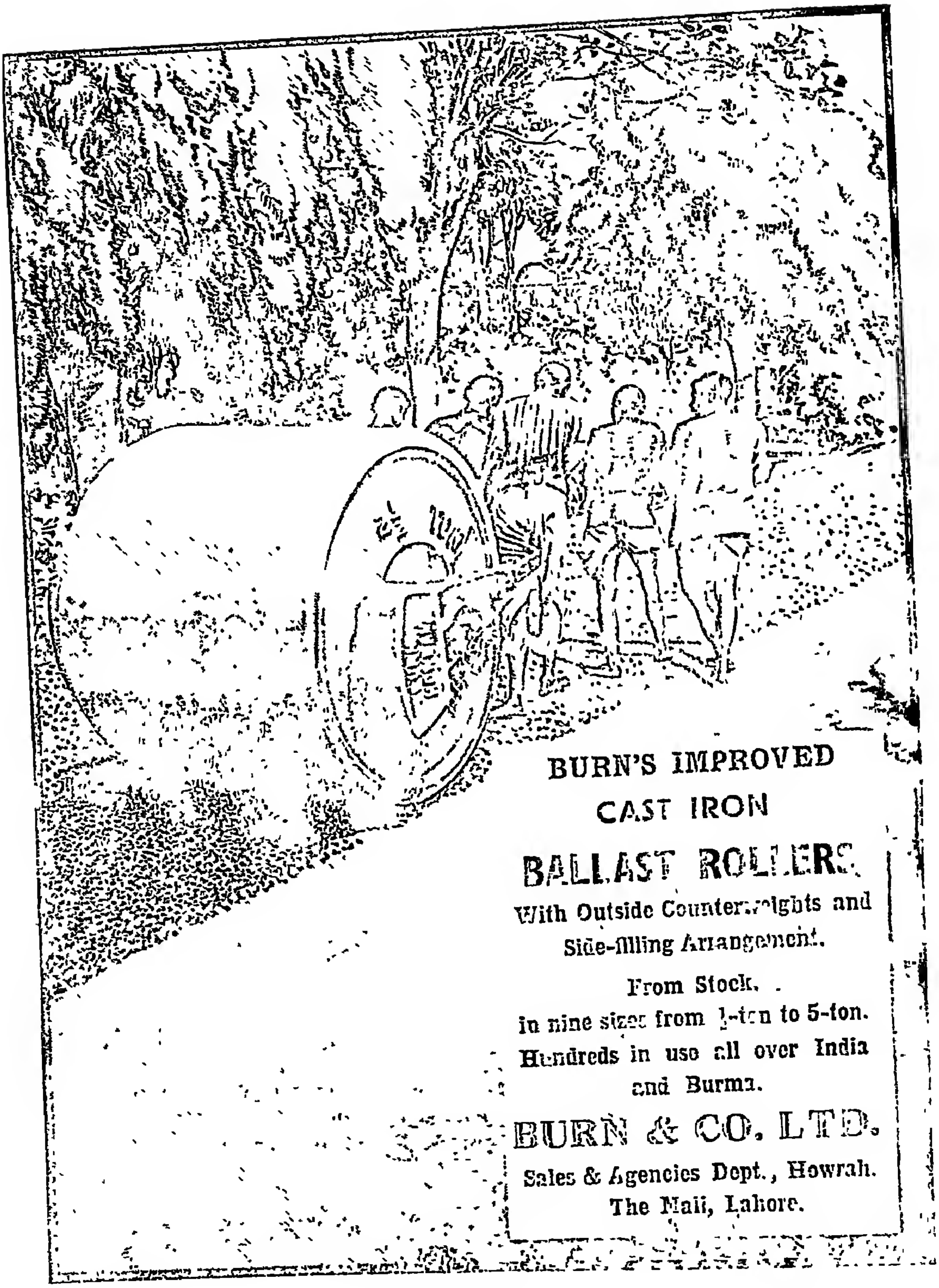
"CRETEWAYS" PROVIDE A CURE



"CRETEWAYS"

of The Indo Burma Petroleum Co. Ltd., Lanywa.

Please turn to the inside front and back covers and page (ix).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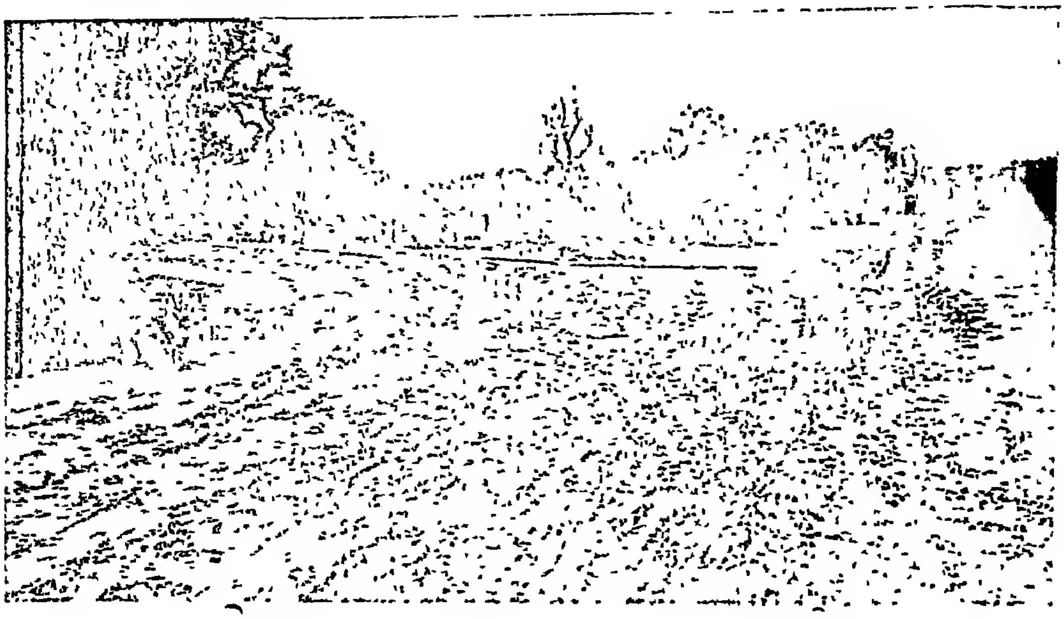
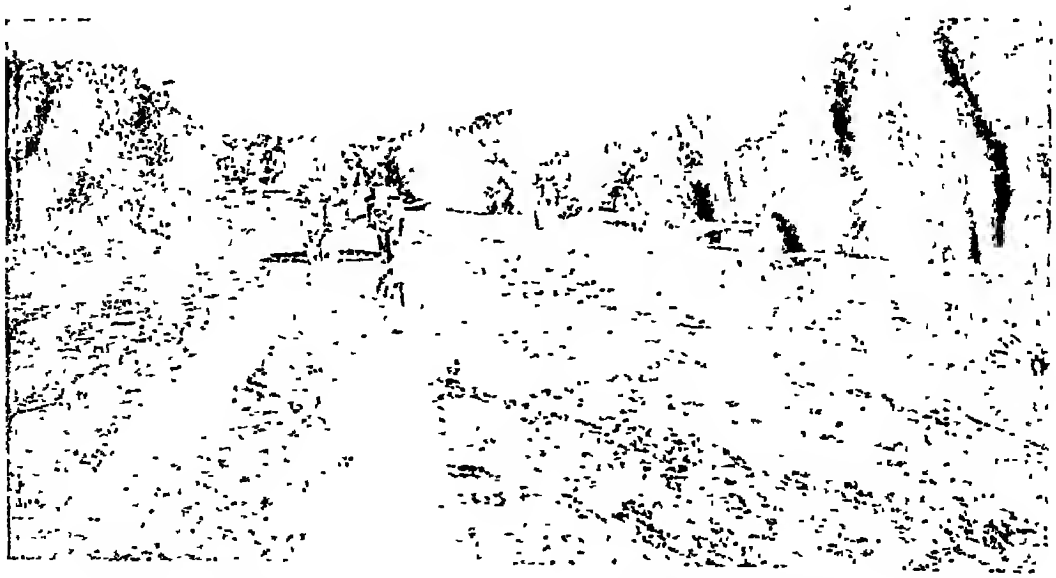


The upper picture shows a section of the Jaranwala-Sayadwala Road in the Punjab. The condition shown in the picture is the result of one day's rain.

The lower picture shows an experimental "CRETEWAY" laid along five miles of this road. This picture was taken at the same time as the illustration above. *Note the hard track provided by concrete, and the consequent absence of ruts and damage to the remainder of the road.* Mud or dust, collecting on the concrete, acts as a cushion which prolongs the life of the track



(Please turn to the inside front and back covers and page vi).

INDIAN ROADS CONGRESS

(*Established 1934*). (*Registered 1937*).

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1940.

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13. Sardar Bahadur T. S. Malik, C.I.E., Chief Engineer, Central Public Works Department, New Delhi.

14. Rai Sahib Tulasi Das Banerji, Garrison Engineer (Factories), Kirkee.

15. Mr. Syed Arifuddin, Chief Engineer, Public Works Department, Hyderabad-Deccan.

16. Rai Bahadur S. N. Bhaduri, Chief Engineer, Gwalior Government, Public Works Department, Gwalior.

17. Mr. M. S. Duraiswamy Ayyangar, Chief Engineer, Travancore State, Public Works Department, Trivandrum.

18. Rao Bahadur K. J. Gandhi, State Engineer, Junagadh State, Junagadh.

19. Mr. B. R. Garudachar, Superintending Engineer, Mysore Circle, Mysore.

20. Mr. Ajit Chand Malhotra, Chief Engineer and Secretary, Patiala State, Public Works Department, Patiala.

21. Mr. K. L. Nanda, Divisional Engineer, Palaces Division, Srinagar.

22. Mr. P. K. Shinde, I.S.E. (Retired), Retired Superintending Engineer, Sykes' Extension, Tarabai Park, Kolhapur.

23. Mr. V. R. Talwalkar, Chief Engineer and Architect, Shivasadan, Pratap Ganj, Baroda.

24. Mr. G. B. Vaswani, Assistant Engineer, Roads, Municipal Corporation, Karachi.

25. Mr. K. S. Ramamurty, District Board Engineer, Vizagapatam District, Watair P. O. (Madras Presidency).

26. Mr. H. E. Ormerod, C/o The Associate Cement Companies Limited, Esplanade House, Waudby Road, Bombay.

27. Mr. D. Nilsson, C/o J. C. Gammon Limited, Hamilton House, Graham Road, Ballard Estate, Bombay.

28. Mr. Ian A. T. Shannon, C/o Burmah-Shell Oil Company Limited, Hongkong House, Calcutta.

29. Mr. Nurmahomed M. Chenoy, C/o The Bombay Garage, Meher, Building, Chowpatty, Bombay.

30. Mr. W. J. Turnbull, C/o The Shalimar Tar Products (1935) Limited, 6, Lyons Range, Calcutta.

31. Diwan Bahadur V. G. Shete, Retired Consulting Public Health Engineer to the Government of Bombay, 322/2 Sadashiva Peth, Poona.

32. Mr. N. V. Modak, City Engineer, Bombay Municipality, Bombay.

33. Mr. W. L. Murrell, I.S.E., Superintending Engineer, North Bihar Circle, Muzaffarpur.

34. Mr. S. Bashiram, I.S.E., Superintending Engineer, Roads, Punjab Public Works Department, Buildings and Roads Branch, Lahore.

35. Mr. N. Durrani, District Board Engineer, Nellore District, Nellore.

MR. JAGDISH PRASAD.

Mr. Jagdish Prasad, whose photograph appears opposite, was Honorary Secretary of the Indian Roads Congress, in addition to his duties as Personal Assistant to the Consulting Engineer (Roads) from November 1936, to September 1940. During his period of office, the Congress grew in size and status, and its office was separated from the Government of India Secretariat to stand on its own feet.

Mr. Jagdish Prasad's great services to the Congress during this period are known to and appreciated by all members.

JAGDISH PRASAD ESQUIRE, C.E., A.M.I.E.,
Secretary, Indian Roads Congress, 1937-1940.

Sixth Indian Roads Congress, Bombay, December 1939.

Proceedings of the Fifth Meeting of the Indian Road Congress.

Volume VI. Bombay. December, 1939.

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APPENDICES.

Proceedings of the Sixth Meeting of the Indian Roads Congress held at Bombay on December 6 to 13, 1939.

The Sixth Session of the Indian Roads Congress commenced at 11 a.m. on December 6, 1939, at the Conference Hall of the Bombay Electric Supply and Tramways Company Limited, Electric House, Bombay. The following members of the Congress were present :—

Madras.

Sri A. Lakshminarayana Rao, Special Engineer, Road Development, Madras.

P. Venkataramana Raju, Esquire, Executive Engineer, South Presidency Division, Chepauk.

K. S. Ramamurti, Esquire, District Board Engineer, Vizagapatam District, Post Office Watair.

P. K. Mukherji, Esquire, District Board Engineer, Masulipatam.

P. G. Mathew, Esquire, District Board Engineer, Mangalore, South Kanara District.

T. Sekharan, Esquire, District Board Engineer, Madura.

S. Narayanaswami Iyer, Esquire, District Board Engineer, North Arcot District, Vellore.

N. Durrani, Esquire, District Board Engineer, Bellary.

B. Satyanarayana, Esquire, District Board Engineer, Kurnool.

T. Lokanatha Mudaliyar, Esquire, District Board Engineer, Coimbatore.

B. Narayanamurti, Esquire, Local Fund Assistant Engineer, Gudiwada.

G. B. Sankaram, Esquire, Local Fund Assistant Engineer, Nazvid, Kistna District.

Bombay.

R. A. Fitzherbert, Esquire, Superintending Engineer, Central Circle, Public Works Department, Poona.

G. D. Daftary, Esquire, Superintending Engineer, Northern Circle, Public Works Department, Bombay.

J. A. S. Manson, Esquire, Executive Engineer, Public Works Department, Surat.

E. A. Nadirshah, Esquire, Hydraulic Engineer, Reservoir Bungalow, Gibbs Road, Malabar Hill, Bombay.

N. V. S. Murti, Esquire, Executive Engineer, Public Works Department, Bombay.

S.S. Divatia, Esquire, Executive Engineer, Public Works Department, Kaira.

A. S. Adke, Esquire, District Local Board Engineer, Dharwar.

G. R. Vartak, Esquire, District Local Board Engineer, Satara City.

N. V. Modak, Esquire, City Engineer, Bombay Municipality, Bombay.

K.G. Bhate, Esquire, Assistant Engineer, Godhra.

B. K. Choksi, Esquire, C/o Public Works Department, Chalisgaon, East Khandesh District.

N. P. Sanjana, Esquire, Chief Engineer's Office, Bombay Port Trust, Ballard Estate, Fort, Bombay.

G. D. Joglekar, Esquire, Supervisor, District Local Board, Thana, (G.I.P. Railway).

P. E. Golvala, Esquire, Civil Engineer, C/o The Chief Engineer, Bombay Port Trust, Ballard Estate, Fort, Bombay.

Bengal.

J. A. Stein, Esquire, Special Officer, Road Fund Works, Bengal Public Works Department, Calcutta.

A. H. Nunn, Esquire, Executive Engineer, Public Works Department, Chittagong

United Provinces.

Mahabir Prasad, Esquire, Superintending Engineer, 1st Provincial Circle, Public Works Department, Lucknow.

W. F. Walker, Esquire, M C, Superintending Engineer, 2nd Provincial Circle, Public Works Department, Lucknow

James Harris, Esquire, District Board Engineer, Saharanpur.

M. A. Mirza, Esquire, Assistant Engineer, Public Works Department, Buildings and Roads Branch, Cawnpore.

Madho Prasad Srivastava, Esquire, Engineer, District Board, Lucknow.

Rai Sahib Lala Fateh Chand, Secretary-Engineer, District Board, Bijnor.

Punjab.

S. Bashiram, Esquire, Superintending Engineer, Roads, Public Works Department, Punjab, Lahore.

Sita Ram Mehra, Esquire, Executive Engineer, 3rd Lahore Provincial Division, Public Works Department, Lahore

Champa Lal, Esquire, Executive Engineer, Montgomery Provincial Division, Montgomery.

Central Provinces.

P. V. Chance, Esquire, Chief Engineer, Central Provinces and Berar, Public Works Department, Nagpur

G. A. D. Cochrane, Esquire, Executive Engineer, West Berar Division, Akola.

Bihar.

W. L. Murrell, Esquire, Superintending Engineer, North Bihar Circle, Muzaffarpur.

S. A. Amir, Esquire, Executive Engineer, Hazaribagh Division, Hazaribagh.

Subodh Kumar Ghose, Esquire, Assistant Engineer, Public Works Department, Chaibasa (Singhbhum).

K. Gupta, Esquire, District Engineer, Chaibasa (Singhbhum).

Assam.

Ali Ahmed, Esquire, Superintending Engineer, Southern Circle, Public Works Department, Shillong.

D. C. Datta, Esquire, Assistant-Engineer, Public Works Department, Post Office Kohima, Naga Hills.

Orissa.

K. Naziruddin, Esquire, Superintending Engineer, Orrissa.

W. R. Fleury, Esquire, Executive Engineer, Sambalpur Division, Sambalpur.

Sind.

W. E. Bushby, Esquire, Special Road Engineer in Sind, Public Works Department, Karachi.

H. B. Parikh, Esquire Superintending Engineer, Sind, (on leave).

G. B. Vaswani, Esquire, Assistant Engineer, Roads, Karachi Corporation, Karachi.

Government of India.
(Communications Department).

K. G. Mitchell, Esquire, C. I. E., Consulting Engineer to the Government of India (Roads), New Delhi.

Jagdish Prasad, Esquire, Assistant to the Consulting Engineer to the Government of India (Roads), New Delhi.

Central Public Works Department.

H. J. Paterson, Esquire, Executive Engineer, Bombay Central Division, Bombay.

Central India States Agency.

G. P. Bhandarkar, Esquire, M. B. E., Chief Engineer, Holkar State, Indore.

Rajputana States Agency.

G. Mc C. Hoey, Esquire, State Engineer, Jaipur State, Jaipur.

M. U. Hasany, Esquire, State Engineer, Tonk State, Tonk.

Ram Narain Chowdhary, Esquire, Assistant Engineer, Jodhpur State.

Western India States Agency.

Rao Bahadur K. J. Gandhi, State Engineer, Junagadh State, Junagadh.

Jagmohandas T. Mehta, Esquire, Town Roads Supervisor, Public Works Department, Bhavnagar.

M. R. Jivrajani, Esquire, State Engineer, Porbandar State, Porbandar.

D. B. Pancholi, Esquire, State Engineer, Dhrangadhra,

Baroda State and Gujarat States Agency.

Vasudeo Ramchandra Talwalkar, Esquire, Chief Engineer and State Architect, Baroda State, Shivasadan, Pratap Ganj, Baroda.

G. K Patil, Esquire, Assistant Engineer, Tapti Bridge, Kathor, (*via* Sayan, Baroda State, B. B. & C. I. Railway).

Eastern States Agency.

A. K. Sen, Esquire, Road Engineer, Tripura State, Post Office Agartala.

J. C. Roy, Esquire, State Engineer, Cooch-Behar State, Cooch-Behar.

S. S. Behera, Esquire, State Engineer, Gangpur State, Gangpur.

Madras States Agency.

M S. Duraiswami Ayyangar, Esquire, Chief Engineer, Travancore State, Trivandrum.

E. G. Salter, Esquire, Superintendent of Transport, Travancore State, Trivandrum.

Kolhapur State and Deccan States Agency.

R. S. Bapat, Esquire, State Engineer, Phaltan State, Phaltan.

V. P. Kanhere, Esquire, State Engineer, Bhor State, Bhor.

R. G. Puranik, Esquire, State Engineer, Jamkhandi State, Jamkhandi.

V. P. Bedekar, Esquire, State Engineer, Miraj State (Senior), Miraj (Senior).

P. K. Shinde, Esquire, Retired Superintending Engineer, Kolhapur State, Kolhapur.

Anant Balvant Haval, Esquire, Ilaqa Panchayat Engineer, Shukravar Peth, Kolhapur.

Punjab States Agency.

Ajit Chand Malhotra, Esquire, Chief Engineer and Secretary, Patiala State Public Works Department, Patiala.

Sardar Balwant Singh Budhiraja, State Engineer, Nabha State, Nabha.

Sardar Ram Sarup, State Engineer, Jind State, Sangrur.

Khan Bahadur J. R. Colabawala, State Engineer, Khairpur Mir's State, Khairpur Mir's.

Hyderabad (Deccan) State.

Syed Arifuddin, Esquire, Principal, Osmania Engineering College, Hyderabad (Deccan).

Dildar Hosain, Esquire, Assistant Chief Engineer, His Exalted Highness the Nizam's Public Works Department, Asifabad, Hyderabad (Deccan).

Nawab Ahsan Yar Jung Bahadur, Chief Engineer and Secretary, His Exalted Highness the Nizam's Public Works Department, Hyderabad (Deccan).

Safdar Ali Shareef, Esquire, Chief Engineer's Office, Hyderabad (Deccan.)

C. Hanumanta Rao, Esquire, Divisional Engineer, Parbhani, Hyderabad (Deccan).

J. C. Hardikar, Esquire, Executive Engineer, Warangal, Hyderabad (Deccan).

M. L. Saberi Yusuf, Esquire, Executive Engineer, Mahboobnagar Division, Mahboobnagar, Hyderabad (Deccan).

S. N. Sivarao, Esquire, Office of the Chief Engineer and Secretary, His Exalted Highness the Nizam's Public Works Department, Hyderabad (Deccan).

Mysore State.

B. R. Garudachar, Esquire, Superintending Engineer, Mysore Circle, Mysore.

D. A. Hukeri, Esquire, Executive Engineer, Shimoga Division, Shimoga.

Gwalior, Rampur and Benares States.

Rai Bahadur S. N. Bhaduri, Chief Engineer, Gwalior Government, Gwalior.

Abdul Jabbar Khan, Esquire, Executive Engineer (Roads), Rampur State, Rampur.

Kashmir State.

K. L. Nanda, Esquire, Divisional Engineer, Kashmir Division, Srinagar.

Business and others.

A. S. Trollip, Esquire, General Manager, Bombay Electric Supply and Tramways Company, Electric House, Bombay.

H. E. Ormerod, Esquire, C/o The Associated Cement Companies, Limited, Forbes Building, Home Street, Bombay.

D. Nilsson, Esquire, C/o J. C. Gammon Limited, Hamilton House, Ballard Estate, Bombay.

E. P. Nicolaides, Esquire, C o J. C. Gammon Limited, Hamilton House, Ballard Estate, Bombay.

D. E. Gough, Esquire, Representative of the Society of Motor Manufacturers and Traders, Limited, 41, Nicol Road, Bombay.

Framroz D. Mehta, Esquire, Chartered Engineer, 63, Fergusson Road, Bombay, 13.

Diwan Bahadur V. G. Shete, Retired Consulting Public Health Engineer to the Government of Bombay, 322, Sadashiv Peth, Poona.

S. B. Joshi, Esquire, Engineer and Contractor, Examiner Press Building, (Top floor), Dalal Street, Bombay.

B. V. Vagh, Esquire, Road Engineer, C/o The Burmah-Shell Oil Company, Bombay.

Ian A.T. Shannon, Esquire, C/o The Burmah-Shell Oil Company, Hongkong House, Calcutta.

Rai Sahib Hari Chand, District Engineer, The Concrete Association of India, 70, Queensway, New Delhi.

I. N. Khanna, Esquire, Asphalt Engineer, C/o The Standard Vacuum Oil Company, New Delhi,

T. R. S. Kynnersley, Esquire, C/o The Associated Cement Companies, Limited, Forbes Building, Home Street, Bombay.

W. J. Madden Esquire, C/o The Shalimar Tar Products (1935), Limited, 16, Bank Street, Bombay.

H. F. Bamji, Esquire, Electrical and Mechanical Engineer, Dawn Hill, Fergusson Road, Bombay, 17.

W. J. Turnbull, Esquire, C/o The Shalimar Tar Products (1935), Limited, 16, Bank Street, Bombay.

Nurmahomed M. Chinoy, Esquire, C o The Bombay Garage, Meher Building, Chowpatty, Bombay.

Narindar Singh Sandhawalia, Esquire, C/o The Shalimar Tar Products (1935), Limited, 16 Bank Street, Bombay.

N. Das Gupta, Esquire, Asphalt Engineer, The Standard Vacuum Oil Company, Calcutta.

Dr. M. A. Korni, Consulting Engineer and Architect, 2, Bishop Lefroy Road, Calcutta.

A. K. Datta, Esquire, Consulting Engineer, 5, Hastings Street, Calcutta.

T. Campbell Gray, Esquire, C/o Shalimar Tar Products (1935), Limited, 2/29 Mount Road, Madras.

C. T. S. Malani, Esquire, C/o The Standard Vacuum Oil Company, Karachi.

D. S. Parmara, Esquire, C/o The Shalimar Tar Products (1935), Limited, A. P. Sen Road, Lucknow.

C. J. Fielder, Esquire, C o Messrs. Turner Morrison and Company Limited, Calcutta.

O. C. Kutty-Krishnan, Esquire, Road Engineer, The Standard Vacuum Oil Company, Thamichetty Street, Madras.

A. Burns-Lawson, Esquire, C o The Hindusthan Construction Company Limited, Ballard Estate, Bombay.

D. G. Sowani, Esquire, Civil and Hydraulic Engineer, 95 Girgaon Road, Bombay 4.

H. S. Batlivala, Esquire, Personal Assistant to Chief Engineer, The Concrete Association of India, Bombay.

Manohar Nath, Esquire, Chartered Engineer, 72 Babar Road, New Delhi.

The Congress was formally opened by His Excellency the Governor of Bombay, on the 11th December 1939.

In asking His Excellency the Governor of Bombay to open the Congress, Mr. K. G. Mitchell, C. I. E., I. S. E., President of the Indian Roads Congress, delivered the following address :—

It is my privilege today to welcome your Excellency on behalf of the Indian Roads Congress, and to express our warmest thanks for the honour you have done us in coming here in the midst of your heavy duties and great responsibilities, to open this our sixth annual session. We greatly prize this recognition of our society and of the utility of its work and I assure your Excellency that your presence is a very real encouragement to all of us. It is my privilege also to welcome our distinguished guests, and, in particular, Mr. J. A. Madan and

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Mr. H. F. Knight, Advisers to your Excellency. Mr. Knight's presence is peculiarly appropriate since, as Secretary of the Indian Road Development Committee over ten years ago, he played an important part in the events leading upto the creation of the Road Fund without which this Congress might never have come into being.

According to the custom on these occasions, before I request your Excellency to declare the Congress open, I must ask you to bear with me while I attempt a brief review of the position of our Society, and of the evolution of roads in India upto the present time, and add thereto certain purely personal opinions regarding future progress. The ideas I propose to lay before you are not new although they may be regarded by some as fantastic. But, Sir, if I may borrow a famous phrase, unless we are to remain in a state of pathetic contentment with our present road system, we must look forward to radical changes in the future in all matters concerning roads, rather than backwards along the grooves by which we have leisurely travelled in the past. And I would venture to remind you that, our generation having seen so many fantasies of yesterday become the commonplace of today, should not be afraid to attack the root causes, however time-honoured and deeply rooted, of the defects which we see.

I will not detain you with a detailed history of our Society. Its genesis was due to the Government of India and to the Road Fund and its continued existence to the active support of the Governments of Provinces and States. It is mainly composed of public servants engaged in the construction and maintenance of roads, with an active leavening of those whose business is professionally or otherwise more or less directly connected with roads. Our object, if I may use a catch phrase which we have coined, is to improve the road-rupee ratio. We have now a membership of about 430, and, by subscriptions and sales of our proceedings and other publications, have built up a balance as at 1st October last of about Rs. 17,500. We cannot, I fear, expect our Society ever to be able to defray the expenses of members attending our annual meetings from the various parts of this great continent. The distances are too great. Nor would it be reasonable to expect the members themselves to do so, more particularly the younger and therefore naturally more progressive whom, in particular, we like to see with us. For that we depend upon the Governments of Provinces and States to send their quota of members, and to those Governments as well as to certain enterprising local bodies who have done the same, I would like to express our cordial thanks for this practical, and indeed vital, recognition of the utility of our work. For the rest our expenses amount to about Rs. 12,000 per annum and our own income to about Rs. 8,000. The balance is to be covered for the present by a subsidy from the Government of India of Rs. 4,000 for which also we are very grateful. But with this support and this small Reserve we now stand on our own feet as a separate entity with our own office and staff, and I am personally convinced that in our *quasi-independence* lies our strength.

Our meeting last year in Calcutta was the first occasion on which the expenses of members attending from Provinces and States were defrayed by their respective Governments instead of by the Government of India. The latter naturally had to set a limit to the numbers and it was gratifying that, last year, the attendance constituted what was

upto then a record one of 112. The attendance this year is even better being 123, of whom 57 are Engineers of Public Works Departments and local bodies from ten Provinces, 40 are Engineers from twenty six States and 19 are private members. Among the Provinces, Madras leads both in the total number and in the number of Engineers of local bodies of whom we have present 11 out of a total from the Province of 14. Bombay comes next with a total of one less and the numbers evenly balanced The largest number of members from any State come, as is natural and appropriate, from His Exalted Highness the Nizam's Dominions who have sent 7 members.

In all Engineering work standardisation is an economy, provided that it is recognised that the forces and vagaries of nature (in which, in our case, I must include road traffic) are not standard throughout this large continent. Opinions differ very vigorously on the merits of anything in the nature of an official Central Road Standards Office for India on the lines of the Railway Standards Office, but I think that we may claim to have created in this Congress an efficient unofficial agency, peculiarly appropriate to a Federal Constitution for the pooling of experience; for such standardisation as may naturally be evolved therefrom; for the prevention of repetition of mistakes, and for the promotion among us of a corporate spirit of unity, service and progress. Sir, our drummer is not dead, but on this more or less public occasion and when the period of my own sojourn in India is, alas, drawing to a close, I would like, if I may presume to do so, to say that Road Engineers in India, whether members of our Society or not, are a genuinely devoted and enthusiastic body of public servants who are second to none in their desire to give the taxpayer the best possible value for his money. We have what must often appear to the public to be the humdrum and at times ineffectual reponsibility of making and maintaining roads, at a cost which, having regard to climate and traffic, challenges comparison with the work of any similar body of men elsewhere. Dual purpose roads are now built and maintained in India on what it is still fair, I think, to call bullock-cart finance. To the road-using public the results may often leave much to be desired, but the wonder to me is that, with the money that is spent, the roads are not often very much worse. The last ten or fifteen years have seen not only a great increase in the number, weight and speed of motor vehicles, but also a steady increase of rural cart traffic, of which a particular example is the carriage of millions of tons of cane for the new sugar industry. On the mean of the three years 1924-5 to 1926-7 the total provision for provincial and local road maintenance in all Governors' Provinces save one (for which the earlier figures are not available) was Rs. 383 lakhs. In 1937-38 the provision was 407 lakhs or an increase of only about 6 per cent in a decade of very great development of traffic. What are to us fabulous sums are spent in other countries on building durable roads, about whose excellence we hear a great deal. The Glasgow-Edinburgh road cost, I believe, £60,000 per mile. The cost of the German motor roads was of the same astronomical order. I once asked the Ministry of Transport to show me what they considered really inexpensive road development, and they sent me to

* The numbers mentioned in President's speech were based on the intimations rece[illegible]ed from members who intended to attend Actually the session was attended by 121 members of whom 53 were P W. D. and Local Board engineers, 38 were State engineers and 30 private members.

Members being public servants were 14 from Bombay and 12 from Madras, of whom 10 were local board engineers

see certain roads in Scotland which they considered a notable achievement at £10,000 per mile, or say Rs. 1,30,000. With us, if a mile of road costs Rs. 30,000—without the lakh—we feel that we are being extravagant and yet we have to carry the bullock cart which would make short work of many of the inexpensive types of road, carrying the traffic of other countries.

Now Sir, having beaten our own drum tolerably loud, I turn to our problems in the immediate future and thereafter. We are faced with the inescapable effects of war at a time when it is impossible for any one to see clearly what those will be. We may reasonably hope that Provincial revenues will not be adversely affected and hence that the Road Engineers' bogey of retrenchment of maintenance charges will not appear. In the past our unfortunate experience has been that when retrenchment is necessary, the axe falls first on repairs as well as on works, and naturally, because of the desire to avoid throwing establishments out of employment. Herein lies a partial fallacy since, in India in particular, road maintenance expenditure is in the main only once removed, if at all, from payments to labour in the adaptation and use of materials provided by nature. But necessity knows no law and an arbitrary cut of "x" percent in the repairs budget is a simple nostrum, if ultimately rather like a boomerang. I would remind you of the story of the Irishman and his donkey. The Irishman reasoned that the donkey, being a patient animal would not notice a gradual cut in his food and could therefore be accustomed to have much less, and even, perhaps, none at all. He therefore reduced rations by ten per cent. a week. The experiment was successful in that the donkey made no complaint, but unfortunately at the end of ten weeks it died, and the owner had to buy another. Sir, that is a frivolous but apt parallel to arbitrary economy on road maintenance, particularly in India where roads are generally of a type which is cheap to construct but is dependent on regular maintenance and renewal. The effects of starvation may not be immediately apparent, but later on deterioration is rapid, and in the end your road may have to be reconstructed at greater cost than has been saved. The rational way to economise on roads is to impose restrictions on traffic. If you cannot do that, you cannot escape the inevitable bill, and maintenance is generally less costly than reconstruction. Nevertheless, if retrenchment comes, the members of this Congress will do what is humanly possible in further stretching the power of the rupee.

Before I refer to the future I wish to remind you briefly of certain aspects of the evolution of roads in India in the 19th and 20th centuries. It is sometimes forgotten that it is the development of railways that has revolutionised agriculture and industry and has, in consequence, created many of our present road problems. Without railways, the growing of money crops, which have to be carried by roads and have largely replaced subsistence farming, would not have been possible. Without railways there would have been little or no organised industry with the resulting migrations of the rural community, partly over roads. The villager is now in a competitive world and is dependent upon efficient methods of agriculture and of marketing. The spread of both is dependent on good roads, and bad roads cause a direct loss in many ways. During this evolution, which has multiplied the traffic, the improvement of rural roads has not kept pace. This lag was aggravated by the last war, after which public attention was

focussed on roads from a different angle—that of motor transport—and the Road Fund was instituted, in 1929. The Fund was intended to supplement the provision previously made for road development, and is even now only about three quarters of the sum provided by Provinces for "original works" in the year 1913-14. The expenditure in that year was almost wholly applied to extending the system of metalled roads. By the year 1929-30—the last before the commencement of the Road Fund—much of the money provided for "original works" on roads was already being applied to the improvement or reconstruction of existing metalled roads rendered necessary by the arrival of motor transport. The provision in 1929-30 was only 9 per cent. above that for 1913-14 and clearly less money was being spent on the provision of new metalled roads in 1929-30 than sixteen years previously. After the Road Fund came the depression, and other sources of money for road development failed. This position has unfortunately continued, and the Fund has for ten years, in British India at least, been virtually the only source of money for development. It is even now, as I have said, substantially less than what was being spent on new metalled roads in 1913-14 and it has been very largely applied to the bridging, improvement and reconstruction of pre-existing metalled roads, leaving little for new construction. Save possibly for a brief spell after the last war, the last quarter of a century has thus seen less money spent annually on new metalled roads than in 1913-14. Moreover the necessity of providing dual purpose roads (*i.e.*, for bullock carts and motor transport) means that a mile of metalled road is more expensive now than 25 years ago.

Thus, upto the commencement of the last war the steadily growing volume of rural transport was being provided for by the extension of the milage of metalled roads, but not as rapidly as was necessary. During the succeeding quarter of a century, with the exception of a brief spell after the war and before motor transport attracted funds to the improvement of existing metalled roads, extension of the metalled road milage was even slower, if it did not, in many parts of the country, virtually cease. A total of about Rs. 235 lakhs has been spent from the Road Fund on providing about 250 new major bridges and causeways together with a large number of culverts and improvements to existing structures, mostly on trunk and main roads. We now have, approximately, 9,000 miles of roads with modern surfaces including surface painting, (all provided within the last 15 years); 38,000 miles of stone metalled roads; 17,000 miles of kankar, moorum and laterite; 20,000 miles of gravel and other inferior types, and 200,000 miles, or 70 percent of the total of 284,000 miles, in nothing better than natural earth. Only in the figures furnished by two Provinces do the totals include village roads, which amount, in the remainder, to a very large additional milage also unmetalled. All the foregoing figures relate to rural roads in British India. I regret that I have not the figures for States. The figures show the immense importance of rural roads at present unmetalled.

When metalled roads could be inexpensively built and maintained for rural traffic, they were regarded as the obvious line of development,

Road Fund 1938—39 including share of Reserve all Provinces except N.W.F.P. 123 21 lakhs. Construction Provincial and Local excluding Burma & N. W. F. P.

1913—14	159.6 lakhs.
1925—26	160.1 lakhs.

and the improvement and maintenance of the earth road as impossible in the face of the growing traffic. In recent years, as the proceedings of this Congress show, Engineers have realised that, without impossibly large sums of money, extention of the metalled road milage is not a practicable panacea for our rural road problems and that, in consequence, it is no longer permissible to take the line of least resistance and to comfort one's self with the doctrine that the earth road is hopeless and may therefore be neglected. They believe that, if any substantial amelioration is to be made, and even if undreamed of wealth is to be used, the possibility of improving earth roads as such must be fully explored. The earlier recent efforts in this direction of a number of Engineers in different parts of India met with varying success and showed that, without a scientific study of the nature and properties of soils with the help of soil scientists, the Engineer was working in the dark. At the instance of this Congress, therefore, the Government of India made provision for the commencement of specialised research into soils in relation to roads at the Punjab Irrigation Research institute under Dr. Mckenzie Taylor, its principal and Dr. A. N. Puri. This work has now been in progress for two years and the results are encouraging. I do not propose to enter into technical details, but I myself believe that, with the knowledge obtained and likely to be obtained and with the practice of sound principles and the help of soil scientists, it should be possible to effect improvement in respect of a large proportion of unmetalled roads not subjected to heavy bullock cart traffic. Where bullock carts are heavy and in considerable numbers we cannot hope that any but very exceptional soils can be made into reasonably good earth roads. For such roads, which, at a rough guess, I would say amount for the whole of India to a total of 50,000 miles, some form of hard top, or some device like, "trackways", is required. Soil research can help us with these roads also, since, if the subgrade soil can be improved, then a less expensive crust can be provided, and trackways can possibly be more widely used than would otherwise be proper.

With reference to the figure of 50,000 miles of new hardtopped road required, which I have guessed above, I have amused myself with an academic computation as follows: Madras is, as we all know, much better equipped with hard surface roads than the rest of India. Including all classes of road other than natural soil, that is modern surfaces, water-bound macadam, moorum, laterite, gravel, etc., Madras, has a total of 26,000 miles which is equivalent to about 19 miles per 100 square miles of area. If the rest of British India were equipped to the same standard on the basis of area, it would have something like 180,000 miles of such roads. Actually in the rest of British India there are 82,700 miles of these and on this computation it seems that it falls below the level attained in Madras by nearly 100,000 miles of surfaced roads of different sorts. This figure must, however, be discounted by the fact that many Provinces include large areas of forest, mountain and in some cases desert land where nothing like the normal intensity of roads is required. These figures are for British India and while the calculation is, as I have said, an academic one, it suggests that my estimate of 50,000 miles of road for the whole of India, which at present need something better than natural earth, is probably not overstated.

I must here say a few words about trackways. These consist of two strips, usually of cement concrete, each about two feet wide, inset in

an earth road to the track of the bullock cart. Members of the Congress who joined the tour at our first meeting in Delhi, saw some small-scale experiments with these. The succeeding five years' experience has encouraged us to lay a further five miles in the Punjab. The theory of the trackway is quite simple. Earth roads have been highly developed in other countries, and a large proportion of such roads in India could be vastly improved were it not for the heavily loaded bullock cart. It is common experience that when an ordinary nine-foot metalled road is provided, the bullock carts cut it into ruts which are perforce followed by other traffic so that the rest of the metalling is of little practical use, but the whole has none the less to be maintained and renewed. If therefore the ruts are laid in durable material, the needs of the bullock cart are provided and the remainder of the road can be maintained as a good earth road for other traffic. The difficulties of keeping to the tracks and of crossing are more apparent than real. The most damaging criticism of trackways is that a metalled road can often be provided at the same or even less first cost. This is true, but we must look to the ultimate cost, including repairs and renewals, and in this respect concrete trackways would, I believe, be very much less expensive than metalled roads in all except very favoured areas Moreover, they are not so liable as is the ordinary metalled road to suffer permanent damage as a result of enforced temporary neglect.

I have, I fear digressed somewhat from my sketch of the evolution of roads in India My object in that sketch was to suggest that, when the time comes, after the war, to take stock of our position, two things will have to be recognised. The first is that if rural India is not to stagnate, very great arrears of road development will have to be made up. The second is that there is nothing in past history to justify a hope that these arrears can be made good by finance from revenue. But a theory of orthodox finance in India has always been that capital can only be used for "remunerative" expenditure, by which is implied expenditure on works against which direct receipts can be brought to account from which to repay loan charges. Therefore roads are not recognised as "remunerative". Taking the long but unorthodox view, the condition of roads that is likely to obtain in India for very many years if only revenue can be used is, I venture to assert, a direct cause of economic loss to the community, and the prevention or mitigation of that loss should now, in my personal opinion, be regarded as remunerative, even though the results cannot be brought directly to book, since in no other way can the necessary improvements be effected. Without wandering into the road-rail controversy, I think I can say without fear of contradiction that our railway system has been developed to a stage relatively far beyond that of the road system. The community can and does support that railway system and I believe that it could equally support a complementary road system developed to a comparable stage. Moreover, to the extent to which railways are handicapped by lack of roads to feed them, the improvement of roads would be remunerative in the form of better railway returns. In the past, whenever a railway could reasonably be expected to be remunerative, it was built out of capital and immediately provided transport for the growing of money crops in a locality where previously they could not be grown,

but it was left to the usually depleted revenues of local bodies or Provincial Governments suddenly to produce the relatively large sums necessary to provide the roads to carry that produce to the railway adequately. Those sums could not be produced, the roads were not provided, and the farmer was left to reach the market on the railway as best he could over an unmetalled road wholly inadaquate for the new traffic. This has resulted in a very unbalanced system of land transport. There was a learned professor of my youth who was fond of saying that, if theory and practice did not agree, then theory must be wrong. Practice is in our case represented in the resulting unbalanced transport system, and the deficiency of good roads, which we see in India today. I believe therefore that, after the war, when the world turns to reconstruction, the position will be clearly recognised and I venture to hope that the impossibility of its cure by accepted theories of finance will also be seen and that India will enter an era of great road building activity, in which a wise use of capital will play a substantial part. As far as it lies in their power, the members of this Congress will be ready for the occasion, and any temporary lull in our work during the war will afford leisure in which we may apply ourselves to more intensive study of the construction problems with which we hope that we are shortly to be faced.

There remains the disturbing factor of the traffic for which we are to design and build the roads of the future. I disagree with those who in their impatience say that the bullock cart should have no place on a modern road. The bullock cart was there first, it is the primary transport of the country for agricultural produce, and in an agricultural country should take first place. But the community, to its own great detriment and loss, continues at present to use a type of cart which is so destructive that earth roads are nearly impassable, dual purpose roads extremely costly, and the segregation of traffic well nigh impossible. Here we find a vicious circle. We say, and rightly, that if the bullock cart could be shod with pneumatic tyres, we could provide and maintain roads at far less expense than at present. But the ordinary trip for a country cart is, for the greater part of its length, over unmetalled roads before the metalled road is reached, and until we can provide better roads right in the villages, how can we expect the cartman himself to take the initiative in changing his cart so that we may be able to give him those better roads? I have sometimes felt that it would be less expensive for the community to abandon the use of bullock carts, except between the field and the village, and to carry agricultural produce to markets by low-speed diesel-engined mechanical transport trains on pneumatic tyres, than it would be to provide an adequate system of roads to market crops in the bullock cart as it is. The individual only knows, however, that carrying costs him little or nothing. He does not realise what it costs him in bad roads and in taxes that go to maintain the roads, and such a development is at present out of the question. But if the bullock carts used on the road, as opposed to those used in the fields, were to change over to pneumatic tyres, not only would about half the number of carts and bullocks be necessary, which would mean a direct saving in carriage, but many more and better roads could be provided for the money now being spent. The change-over is, however, expensive for the individual, and much financial help and encouragement are necessary. I believe therefore that, situated as we are, the public money necessary to bring about this change should be recognised as an appropriate part of road

finance. It might well be an economy in the long run to put money into carts which do no damage rather than into roads which will cost a great deal to maintain with the present types of cart.

Sir, I have meandered over a wide field in which I have addressed myself largely to the question of the primary necessities of adequate rural transport and have said nothing about our main and trunk roads. This is not because I do not consider the latter and the development of motor transport on them to be of great importance. It is because, to my mind, the wholesale improvement of rural transport facilities, leading to a far wider use of motor transport also, is immeasurably more important, having regard to the milage of roads involved, the number of people served, and the primary industry—agriculture. I could say much about the need for segregation of traffic for safety on main roads, and for improving the trunk roads, but both of these are a function of money and the bullock cart. Improve that cart and the rest is much easier. There are also many vocal people to advocate better trunk roads, but few seem to me to voice the real necessity. The land transport system is unbalanced and the redress of that lack of balance is an urgent necessity. If rural road and transport problems can be successfully attacked and, in particular, if the bullock cart can be modernised, then many of our other problems will be easier of solution. India cannot stand still, but must go forward, and, in thanking Your Excellency once more for the honour you have done us by your presence here today, I would repeat that this Congress and its individual members may be relied upon to play an efficient part in that progress when the time comes.

His Excellency then addressed the Congress as follows:—

Mr. President and Gentlemen,

It is a source of satisfaction to me that the Sixth Meeting of the Indian Roads Congress is being held in Bombay City and I offer you a very hearty welcome amongst us and trust that your stay may be both pleasant and profitable.

This session is significant in that you have chosen as your President one who may well be described as the Father of this Congress, and it may fairly be said that Mr. Mitchell knows as much about the roads of this vast sub-continent as any other man alive and that his contribution to the various and complex problems which have arisen has been of enduring value.

I feel sure, Mr. President that you can look with great satisfaction on this organisation which you have done so much to initiate and foster, and that from your well earned retirement you will view with interest and sympathy the efforts of your successors to build on the foundations which have been laid.

Many of you have been able to visit during the past few days various Road works either completed or in progress in the neighbourhood and will have appreciated the great variety of problems presented to the road-engineer in this Province. A well-known advertisement tells us that a man is as old as his arteries. I think you will have found that we cannot claim to have reached anything approaching

maturity, but of this I am confident, that you, Gentlemen, are giving us most valuable assistance in cutting our wisdom teeth.

The importance of the subject with which the Congress is concerned is one which, in my estimation, it would be impossible to exaggerate. Communications are, in very truth, the arteries of the economic, social and political life of a country and in the active pursuit of your subject you are making no mean contribution to the building not only of roads and bridges but of a healthier, happier and more prosperous India. We cannot afford road construction of the expensive character to be found in Europe and America and certainly for many years to come the railways must remain the principal means of long distance communication. It is the function of the various administrations concerned to lay down the broad lines of policy to be followed and I feel, Mr. President, that you have done well in having elected for your swan-song to survey this road problem on the broadest lines with a view to indicating how a communications system, well balanced and related to other methods of transport might be secured. And I welcome further your angle of approach to this vital question. The peasant is the backbone of the country and everything which adds to his betterment increases the wealth of the country as a whole. I am not unaware of the inevitable clash of interest between roads and railways and between the motorist and the cultivator. A high degree of realism is necessary if the best is to be made of the limited resources at our disposal, and your survey, Mr. President, from the view point of the agriculturist is both reasonable and necessary. The bullock might well be classified, as you have suggested, amongst the forces and vagaries of nature, and any scheme for development which omits to pay due regard to bullock-transport must fail of its purpose. To an audience such as this it may appear presumptuous to dwell upon the importance of putting the peasant in closer touch with his market, but I do feel that the need cannot be overstressed. The Indian cultivator competes in a world market and it is no solution of his problem that cities such as Bombay have modern-surfaced roads if cotton and grain cannot reach the market at competitive prices. Equally it would seem to me of greater benefit to the economic life of the country that rural roads should be improved than that the motorist should be able to travel in comfort on a modern surface from Bombay to Calcutta, Madras or Delhi. Do not misunderstand me. The problem must be viewed from the broadest angle and I am far from suggesting that the motorist, who oftentimes regards himself as over-taxed, but who certainly provides his share of the financial sinews, should be regarded as a trespasser on the roads. But I apprehend that the motorist would react very violently if the authorities abandoned road maintenance in favour of, say, landing grounds and other facilities for air-transport and in the same way the agriculturist estimates what is done about roads by the advantage which is brought to him and his community.

I have heard with great interest, Mr. President, your remarks on the technical difficulties in providing any considerable extension of metalled road mileage and I have every confidence that this Congress will do all that lies in its power to assist in bridging the very wide gulf which now exists between finance and present costs of construction. It will be of interest to you all to learn that last year my Government appointed

a Committee to investigate the question of the most suitable types of roads for villages. Their report is now under examination and I have not the least doubt that before conclusions are reached we shall often refer hopefully to the records of your deliberations and researches.

This brings me to the inevitable question of finance. If I have acclaimed you, Mr. President, as the Father of the Congress, I think it will not be out of place to accord the maternal role to Necessity, proverbially the mother of invention. Gentlemen, it would be vain to fail to recognise that many great problems still seek a solution and equally that our resources are very limited. It is not your function to discover new sources of revenue, but we do look to the wealth of experience and skill here assembled to produce results which will enable us to make the best of the funds available—to improve in the phrase you, Mr. President, have used, the road-rupee ratio. The creation of the Central Road Fund has in this Province helped materially to meet some of the difficulties in respect of trunk and feeder roads while considerable sums have been set aside in recent years from provincial revenues for village roads. I cannot pretend, however, that either source will, in any measurable period, achieve as much as we should like. You, Mr. President, have described as unorthodox the suggestion that roads should be financed from loan funds, and I think you also suggested that, to some, the idea may sound fantastic. You will not expect me to deliver any final verdict on this grave question, but I may at least agree that we should not in matters of this kind allow undue weight to be attached to a strict balancing of costs and visible returns. The benefits which must result from a sound system of communications cannot be calculated by the actuary. Many of them are intangible and, for that very reason, the more valuable.

Gentlemen, I shall not detain you further. I thank you for inviting me to open this meeting and I trust that your deliberations may be successful. I now declare the Sixth Meeting of the Congress open.

Monday, December 11, 1939.

PAPER C—39

Mr. N. V. Modak (Chairman) :—I call upon Mr. A. K. Datta to introduce his paper "Development and application of ' village cement ' and high-silica portland cement for construction of concrete roads."

The following paper was then taken as read :—

PAPER No. C—39.

DEVELOPMENT AND APPLICATION OF "VILLAGE CEMENT" AND HIGH SILICA PORTLAND CEMENT, FOR THE CONSTRUCTION OF CONCRETE ROADS.

BY

A. K. DATTA, B.E., C.E., M.I.E. (IND.)

At the Fifth Annual General Meeting of the Indian Roads Congress, held in February, 1939, at Calcutta, the author referred to this subject in the discussion of a paper but as it was not possible to discuss the matter in details, he was requested by members in that meeting to write a paper on this subject.

We find that Cement Concrete roads are not making a rapid headway in India inspite of the excellent qualities of the same, such as, long life, non-skidding smooth surface and least cost in maintenance. From the reports published in the June 1938 issue of "Indian Roads" we find that out of 200,000 miles of roads, there were not even 200 miles of concrete roads up-to-date. The reason for this is attributed to high initial cost of concrete roads. The reason for the high cost of concrete roads is the high cost of cement combined with the high cost of transport.

Now the problem comes in—" How can we reduce the cost of cement and the cost of transport ? " This is a very important problem for the Road Engineers to consider. This problem has been engaging my attention for several years past. In the year 1937, the author discussed that point in one aspect in his paper No. 35 on "Economy and Development of Bonded Brick Concrete roads, Plain and Reinforced" at the Lucknow Session of the Indian Roads Congress and said that for the rapid development of concrete roads in India, we wanted:—

1. Supply of cement at cheaper cost.
2. Cheap transport cost.
3. Replacement of concrete by bricks in the lower part of concrete roads *i.e.*, by using Bonded Brick Concrete, Plain and Reinforced, thereby reducing considerably the cost of construction.

Now the price of cement at the factory site has come down to a certain extent but on account of the high transport cost, the cost of cement still continues to be fairly high at the site of the works. The price of cement may also go up again.

The author started investigations in this matter to find out how can we get cheap cement for road construction. Extensive experiments were conducted at Dalmia-nagar Cement Laboratory and elsewhere for a long period to find out if it were possible to manufacture cheap cement without investing large sums of money and without deterioration of the quality. By these

experiments, the author developed two processes of manufacture, the specifications of which are as follows:—

I. "VILLAGE CEMENT."

The process is a method of manufacturing hydraulic cements and limes for constructional and road works by mixing together slaked lime and clay in required proportions, made into bricks or lumps and then burning the same at preferably high temperature in ordinary brick or lime-kilns, and finally, grinding the burnt stuff with a small percentage of gypsum, usually 5 per cent or so, to fineness of cement specification. The object of adding gypsum is to prevent too rapid setting, also to prevent expansion due to the slaking of any free lime.

In usual cases, cement factories are situated at limestone quarries or at sites near by. Important towns and cities which are usually situated at long distances, away from such stone quarries, cannot have any such factory on account of the high cost of the transport charges for stones.

Again, ordinary procedure for the manufacture of Portland cement is to burn to fusion a finely powdered mixture of limestone and clay, either wet or dry, in a rotary kiln, thereby producing cement and these clinkers are allowed to cool and aerate for a few days and after that they are ground very finely with a small percentage of gypsum.

In an ordinary cement factory, the important parts are:—

(*a*) A Crusher, which crushes limestone into small pieces.

(*b*) The Raw Mill, which crushes the limestone pieces into fine impalpable powder or paste and mixes it with clay in requisite proportions.

Those two parts are practically eliminated in this new process in which slaked lime, which is already a fine impalpable powder, is used with clay. For a small scale operation, an ordinary Pan Roller-mixer will be quite good for that mixing.

In limestone quarries it is easy and cheap to burn the limestone into quicklime and the same can be easily transported. By burning, limestone loses about 40 per cent of its weight. The action is represented by the equation

$CaCO_3$	$= CaO$	$+ CO_2$
Limestone	= Quicklime	+ Carbon dioxide (gas).
100	= 56	+ 44.

So the cost of transport of quicklime will come out to be much cheaper than original stones, which are heavier.

By this process we see that we can do away with the Crusher and the Raw Mill. We make bricks or lumps from the mixture of lime and clay by adding suitable quantities of water. These lumps of bricks are allowed to dry up and are then burnt in lime-or brick-kilns and finally we get good hydraulic lime or cement according to the nature of mixture and nature of burning. The whole thing is to be ground well with a small percentage of gypsum or Plaster of Paris.

By this process it is quite easy to manufacture hydraulic limes and cements at any place without much investment. That is just like burning bricks at any required site by making a mixture of lime and clay.

A series of experiments on that line were made by making various mixtures of lime and clay and mould bricks from these mixtures and the same were burnt, in brick or lime-kilns at Dalmia-nagar. In case of brick-kilns, these bricks were burnt till they assumed yellowish colour. They could then be easily powdered into finely ground hydraulic lime without much trouble. In the case of the burning of the bricks in the lime-kiln, the bricks were cut into smaller lumps before putting the same as charge in the lime-kiln with alternate layers of coal. In the case of lime-kiln burning, a part of those bricks was burnt into fusion into cement clinkers. The author separated the lime and the cement clinkers and got them aerated and then ground to cement specification with gypsum. The cement from the clinkers gave much higher results in strength than the hydraulic lime and in the case where 25 per cent of Portland cement clinkers were mixed with 75 per cent of these clinkers, the author got the results almost as high as those of Portland cements with age. In India, we have got brick and lime-kilns, spread over almost every part. In those kilns, we can get these hydraulic cements made without much difficulty and these cements and hydraulic limes, when ground well with hard-burnt or over-burnt *soorkhi*, will produce a mortar rivalling with best Portland cement in strength. We have seen many tests in the Test results of lime with *soorkhi* and sand. The tensile strength of 3 *soorkhi* : 1 lime (by volume) was found to be, in the case of Dewarkhand lime, as 135 pounds per square inch in 14 days, 256 pounds in 28 days, 399 pounds in 3 months and 428 pounds per square inch in 6 months, whereas, the results with sand in 1 : 3 by volume (See Appendix I, Expts. A & A2) were as follows:—

14 days	.. 17 pounds per square inch.	28 days	.. 23 pounds per square inch.
3 months	.. 47 pounds per square inch.	6 months	.. 52 pounds per square inch.

These results show that there is a hydraulic action between lime and *soorkhi* which made the strength of the same about 10 times the strength of sand-lime mortar, that means, there has been 'cementic' action in that mortar.

Referring to "Encyclopædia Britannica" page 110, under heading "Cement" we find the extract on Puzzolanic cement as follows: "Lime, in the presence of water, readily combines with the silica in the active state and forms Calcium silicate, similar to that of Portland cement. Various natural and artificial materials, such as, Puzzolana, trass, Kaiselguhr pumice, tufa, santorin earth, granulated slag etc. contain active silica and when the cost is low, they make a useful addition to the lime mortar. To obtain the best effect, the granulated slag or other material should be ground with the lime until both materials are in fine state of division and intimately mixed. When properly made, Puzzolanic cement will attain a strength approaching that of Portland cement and the bulk of puzzolanic material also act as an aggregate instead of active constituent of the cement."

In the present case, when we burn clay with the lime, part of the lime comes in combination with the clay and forms Calcium silicate and Calcium Aluminate, as in the case of Portland cement. Also, the clay which does not enter into combination with the lime after being burnt, contains a lot of active silica and this active silica easily combines with the free lime and forms Calci m silicate which in turn sets very hard. Hardburnt *soorkhi* is artificial Puzzolana.

About 2000 years back, ancient Romans made a kind of cement and built Concrete structures with it, which endure to-day. The constituents of Roman cement were roughly 40 per cent lime and 60 per cent clay. The Roman cement was made from volcanic ash called Puzzolana and lime and that lime was manufactured by burning limestone nodules containing about 40 per cent lime and 60 per cent clay. The Roman cement concrete structures built under sea-water in many parts of England are in excellent condition now after a period of over 2000 years. The Roman cement was also of yellowish colour, burnt at a comparatively low temperature, say, about 800 degrees Centigrade to 900 degrees Centigrade. Our new cement, made by burning the mixtures of lime and clay, also is of yellow colour and of similar properties as of Roman cement and the strength of that cement will be increased by adding artificial Puzzolana which is hard-burnt or over-burnt or fused brick dust or *soorkhi*. On grinding the *soorkhi* to great fineness, we shall be able to increase considerably the strength of the cement mortar. The cement produced by these manipulations we shall call "VILLAGE CEMENT" or "HYDRAULIC CEMENT".

II. "HIGH SILICA PORTLAND CEMENT".

The author's next investigation was to find out how to increase the strength of the Portland cement without increasing the cost of the same. This was found in High-Silica portland cement.

High-Silica portland cement is much stronger and better in many respects than ordinary portland cement. This cement produces more durable structures, with better water-proof, weather-resisting, and heat resisting qualities than ordinary portland cement. When portland cement sets, there is a partial splitting of limerich silicates with the liberation of slaked lime. The hydration product of the portland cement contains a large percentage of lime in the free condition, even many weeks after hardening. This amount of free lime is about 11 per cent of the cement. This lime is visible also in the form of white lather on a wet mixture of cement mortar or concrete. This lime is a source of weakness in the portland cement mortar or concrete to the action of chemically aggressive agents It is for this weakness that portland cement concrete had been reported in so many cases to have failed under sea-water. The special feature of this High-Silica cement is that the free lime in the portland cement is neutralised by adding active silica which combines readily with the lime and forms Calcium silicate, the strong binding material in all portland cements. Thus, on account of the binding power of the Calcium silicate, the resultant High-Silica cement is expected to be much stronger than the portland cement. The author tried extensive experiments by adding this active silica in different proportions with the cement clinker or cement and got very encouraging results.

With the addition of 25 per cent to 35 per cent active silica to the cement clinker or cement, the resultant High-Silica cement was found to be very much stronger than the mother portland cement with age In certain cases, say, with 35 per cent of active silica, strength as high as 845 pounds per square inch was obtained for a 3 1 sand cement mortar in 1½ months, *vide* appendix 1 Expt. No. 44

High-Silica portland cement is slightly darker in colour, than ordinary portland cement. It satisfies all the physical tests about fineness, setting time, soundness and tensile strength. In tensile tests, it is much superior to ordinary portland cement with age. With the addition of 25 per cent of the

active silica, it satisfies all chemical tests of the British Standard Specification except the insoluble residue. The active silica is prepared by burning clay at very high temperature, when clay will be burnt to clay clinkers. The clay clinker is very rich in active silica and active alumina. The active silica combines with lime to form Calcium silicate and the alumina combines with lime to form Calcium Aluminate. It is very well known what an important part is played by alumina in Alumina cement.

Referring to Explanatory Handbook on the Code of Practice for Reinforced Concrete, by Scott and Granville, on page 8, we find (reproduced below), typical compositions of the various cements marked as (1), (2), (3) and (4). Column (5), added by the author, is for High-Silica cement.

Percentage composition of cements.

	(1) Normal Portland cement.	(2) Rapid Hardening cement.	(3) Portland Blast furnace cement.	(4) High alumina cement.	(5) High silica cement. (Datta) 65/35 II	75/25 I
Lime CaO	64	65	57	40	42.6	53.7
Silica (SiO_2)	20	20	24	5	44.2*	32.9*
Alumina (Al_2O_3)	7	6	8	40	5.7	4.9
Iron Oxide (Fe_2O_3)	3	2.5	3	12	2.3	2.3
Sulpher Trioxide (SO_3)	2	2.5	2	none	1.4	1.75

* These figures include soluble silica and insoluble residue.

The lime content in High Alumina Cement is 40 per cent only, whereas the lime content in ordinary portland cement is 64 per cent, *i.e.*, much higher than the lime content of High Alumina Cement. The strength of the High Alumina Cement is very much greater than that of normal portland cement. Referring to page 7 of the book referred to above, we find the average crushing strength of 1 : 2 : 4 concrete with the different cements as follows:—

	3 days	7 days	28 days.
Normal portland cement	1450 lbs.	2400 lbs	3800 lbs.
Rapid hardening portland cement ..	2250 lbs.	3500 lbs.	4800 lbs.
High Alumina cement	5750 lbs.	7600 lbs.	8500 lbs.
High Silica cement No. 1	5450 lbs. in 22 days.		
High Silica cement No. 2	6624 lbs. in 22 days.		

Tests of High Silica cement as compared to Normal portland cement.

Tests	Particulars	Normal portland cement		High Silica cement		B.S.S. 1931-No. 12
		Dalmia brand	Star of India (A.C.C.)	75/25	65/35	
Chemical composition	Lime (CaO) ..	64.82	63.84	53.72	42.6	
	Soluble silica-(SiO2)	21.56	22.10	32.89	44.24	Not more than 1%
	Insoluble residue ..	.88	.60			
	Alumina (Al_2O_3)	5.59	4.82	4.93	5.72	
	Iron Oxide (Fe_2O_3)	2.19	2.26	2.36	2.3	„ 4%
	Magnesia (MgO) ..	2.59	3.21	3.24	2.99	„ 2.75%
	Sulphur (SO_3) ..	1.45	2.04	1.75	1.43	
	Loss of ignition ..	1.2	1.12	1.34	1.55	„ 4%
		100.28	99.99	100.23	100.83	
	Net proportion of lime to silica and alumina	2.75	2 68			Between 2 and 3
Fineness of grinding	Residue on mesh 170 and 72	2.52% 0.02%	2.22% 0.02%	2.2% .15%	2.0% 0.12%	Not more than 10%
Tensile strength cement and sand	3 days	512 lbs.	485 lbs.	533 lbs.	534 lbs.	Not less than 300 lbs.
	7 „	532 lbs.	532 lbs.	553 lbs.	568 lbs.	Not less than 375 lbs.
	27 „	x	x	662 lbs.*	795 lbs.*	
Setting time	For normal cement (a) initial	107 mts.	80 mts.	100 mts.	95 mts.	Not less than 30 mts.
	(b) final	2 hrs. 25mts.	1 hr. 56 mts.	2 hrs. 29 mts.	2 hrs.- 29 mts.	Not more than 10 hrs.
Soundness	Expansion after boiling in La Chatelier mould unaerated cement	1 m.m. sound	$1\frac{1}{2}$ m.m. sound	1 m.m sound	1 m.m. sound	Not more than 10 m.m.
Proportion of water used in gauging	(a) setting time ..	23.2%	22.9%	23%	23%	
	(b) cement & sand briquettes	8.3%	8.2%	$7\frac{1}{4}$%	$7\frac{1}{2}$%	
	(c) Temperature during test	86°–94°F	80°–96°F	94°F	95°F	..
Test certificate No. and date	Government Test House at Alipore	271 CM dated 26-4-38	174 CM dated 17-4-37	Dalmianagar Lab. dated 21-5-38	dated 21-5-38	

* With time the High Silica cement becomes much stronger than normal portland cement, both in tension and in compression,

APPENDIX—I

EXPERIMENTS ON HIGH SILICA CEMENT.

Test No. Ref.	Particulars	Prop. Cem.-Sd.	% of water	No. of Brqts.	Tensile strength per sq. in.			Remarks.
					3 days	7 days	28 days 66	
No. 8	C. Cl. 75 Jhama 25 Gypsum 5% of Cl.	1:3	8%	12	485 lbs 475 „ 495 „	510 lbs. 540 „ 530 „	740 lbs. 700 „ 600 „	
					485 „	527 „	680 „	Average.
No. 9	C. Cl. 65 Jhama 35 Gypsum 5%	1:3	8%	12	450 lbs. 450 „ 445 „	500 lbs. 475 „ 490 „	715 lbs. 600 „ 630 „	
					448 „	488 „	648 „	Average.
No. 27	C. Cl. 75 Jhama 25 Gypsum 5%	1:3	8%	12	550 lbs. 480 „ 490 „	565 lbs. 530 „ 540 „		
					507 „	545 „		Average.
		COMPRESSION				TEST-7cm³		
No. 29	C. Cl. 100 Gypsum 5%	1:3	12½%	12	5 tons	7 tons.	9.5 tons	
No 31	C. Cl. 75 Jhama 25 Gypsum 5%	1:3	8%	5	500 lbs. 500 „	575 lbs. 530 „	620 lbs.	
					500 „	553 „		
		COMPRESSION				TEST-7cm³		
No. 32	C. Cl. 75 Jhama 25 Gypsum 5%	1:3	8%	2	16 tons	11 days 18 tons	1m-20 ds. 19 tons	

EXPERIMENTS ON HIGH SILICA CEMENT.—*(Contd.)*

Test No. Ref.	Particulars	Prop. Cem.-Sd.	% of water	No. of Brqts.	Tensile strength per sq. in. 3 days	7 days	28 days	Remarks.
No. 33	C. Cl. 75	1.3	8%	6	390 lbs.	450 lbs.		
	Jhama 25				440 ,,	490 ,,		
	Gypsum 5%				410 ,,	5 5 ,,		
					413 ,,	482 ,,		Average.
No. 34	C. Cl. 65	1·3	8%	2	460 lbs.	565 lbs.	1m. 20 ds.	
	Jhama 35				500 ,,	480 ,,	680 lbs.	
	Gypsum 5%				480 ,,			
					480 ,,	523 ,,		Average.
No. 43	C. Cl. 75	1:3	7¼%	12	540 lbs.	560 lbs.	630 lbs.	
	Jhama 25				530 ,,	550 ,,	660 ,,	
	Gypsum 5%				530 ,,	550 ,,	680 ,,	
							640 ,,	
							700 ,,	
					533 ,,	553 ,,	662 ,,	Average.
No. 44	C. Cl. 65	1:3	7½%	12	475 lbs	565 lbs.	720 lbs.	
	Jhama 35				580 ,,	565 ,,	780 ,,	
	Gypsum 5%				500 ,,	575 ,,	830 ,,	
					580 ,,		845 ,,	
					534 ,,	565 ,,	5 ,,	Average,
No. 45	C. Cl. 50	1.3	7¼%	12	440 lbs.	405 lbs.	635 lbs.	
	Jhama 50				390 ,,	415 ,,	560 ,,	
	Gypsum 5 % of 50				350 ,,		600 ,,	
					425 ,,			
					401 ,,	410 ,,	598 ,,	Average.
No. 46	C. Cl. 100	1:3	8%	12	560 lbs.	640 lbs.	710 lbs.	
	Gypsum 5%				635 ,,	735 ,,	655 ,,	
					650 ,,	725 ,,	625 ,,	
						630 ,,	625 ,,	
							675 ,,	
					615 ,,	697 ,,	658 ,,	Average.

EXPERIMENTS ON HIGH SILICA CEMENT. (*Contd.*)

Test No. Ref.	Particulars	Prop. Cem. sand	% of water	No. of Brqts.	Tensile strength per sqr. inch: 3 days	7 days	28 days	Remarks.
No. 47	C. Cl. 50 Jhama 50 Si-lime 15 Gypsum 5% of 50	1:3	8%	6	1 day 275 lbs. 320 ,,	x	17 days 610 lbs. 630 ,, 570 ,,	
					298 ,, ,,		603 ,,	Average.
No. 49	Cement 1 sand 3	1:3	8½%	12	2 days 440 lbs. 440 ,, 460 ,,	3 days 520 lbs. 400 ,, 515 ,,	7 days 530 lbs. 530 ,, 580 ,,	
					447 ,,	508 ,,	546 ,,	
No. 56	Pressed mud Cl. 75 C. Cl. 25 Gypsum 5% of 75	1:3	8%	6	26 days 490 lbs. 460 ,,	1 m.-16 d. 680 lbs. 640 ,, 670 ,,		
					475 ,,	670 ,,		Average.
No. 57A	Pressed Cl. 75 C. Cl. 75 Gypsum 5%	1:3	8%	6	x	19 days 490 lbs. 480 ,,	1 m-15 d 680 lbs. 640 ,, 690 ,,	
						485 ,,	670 ,,	Average.
No. 65	C. Cl. 75 Jhama 25 (Cawnpore) Gypsum 3·075	1:3	8%	8	510 lbs. 510 ,, 495 ,,	520 lbs. 550 ,, 535 ,,	39 days 600 lbs. 660 ,, 615 ,,	
					505 ,,	542 ,,	625 ,,	Average.
No. 67	C. Cl. 65 Jhama 35 Gypsum 3.25	1:3	8%	12	480 lbs. 510 ,, 475 ,,	525 lbs. 535 ,, 500 ,,	33 days 795 lbs. 710 ,, 765 ,,	Note the high strength.
					488 ,,	520 ,,	757 ,,	

EXPERIMENTS ON HIGH SILICA CEMENT.—(Contd)

Test No. Ref.	Particulars	Prop. Cem -Sd.	% of water	No. of Brqts.	Tensile strength per sq in. 3 days	7 days	28 days	Remarks.
No. 69	C. Cl 75 Jhama 25 (Calcutta) Gypsum 3.75	S.W. S C 3.1	8%	12	2 days 475 lbs. 460 ,,	3 days 485 lbs. 480 ,, 480 ,,	24 days 605 lbs. 655 ,, 680 ,,	
					467.5	482 ,,	647 ,,	Average.
No. 70	C Cl 75 Jhama 25 (Cawnpore) Gypsum 3 75	1 3	8%	6	490 lbs 590 ,, 550 ,,	×	715 lbs. 740 ,,	
					543 ,,		727 ,,	Average.
No. 71	C Cl. 75 Jhama 35 (Cawnpore) Gypsum 2 5	1:3	8%	6	465 lbs.	475 lbs. 510 ,,	22 days 715 lbs. 730 ,,	Note the high final Strength
						492 ,,	723 ,,	Average.
No. 72	C. Cl. 50 Jhama 50 (Cawnpore) Gypsum 2.5	1.3	8%	6	425 lbs. 400 ,,	550 lbs. 500 ,,	22 days 630 lbs. 625 ,, 610 ,,	
					413 ,,	525 ,,	622 ,,	
					(Cube test) 7cm². COMPRESSION			
No 73	C Cl. 75 Jhama 25 (Cawnpore) Gypsum 3.75	1 3	8%	4	×	15 tons 7 tons	22 days 20 tons 17 tons	
						11 tons	18 5 tons	Average.
No. 74	C. Cl 75 Jhama 25 (Cawnpore) Gypsum 3.75	1 3	8%	2	×	×	22 days 18 tons 17 3 tons	
							17.65 tons	Average.

EXPERIMENTS ON HIGH SILICA CEMENT.—(*Concld.*)

Test No. Ref.	Particulars	Prop. Cem.-Sd.	% of water	No. of Brqts.	Tensile strength per sq. in. 3 days	7 days	28 days	Remarks.
No. 75	C. Cl. 65 Jhama 35 (Cawnpore) Gypsum 3.75	1:3	8%	4	(Cubic C.M.) ×	9 tons 8 tons 8.5tons	22 days 25 tons 20 tons 22 5 tons	Note the high Strength Average.
No. 76	C Cl. 50 Jhama 50 (Cawnpore) Gypsum 2.5	1:3	8%	4	(Cubic C.M.) ×	5 tons 10 tons 7.5 tons	22 days 22 tons 15 tons 18.5 tons	Average.
No. 6	Jap. Silica Cement	1:3	8%	6	2days 455 lbs. 500 „ 490 „ 482 „	7 days 530 lbs. 540 „ 515 „ 528 „	×	Average.
No. A1	Alipur Test House. No. 3042 M.D. D. 6-1-37 Dewarkhand Slaked lime-1 Soorkhi -3 (By vol.)	1:3	..	..	14 days 135 lbs	28 days 256 lbs.	3 months 399 lbs.	6 months 428 lbs.
No. A2	Ditto. Dewarkhand Slaked lime-1 Standard sand -3	1:3	..	..	14 days 17 lbs.	28 days 23 lbs.	3 months 47 lbs.	6 months 52 lbs.

C. Cl. = Cement Clinker. Pr. Mud = Pressed mud. Gyp = Gypsum

Note :—The strength of high Silca Cement exceeds Portland cement with age.

DISCUSSION ON PAPER C—39

Mr. A. K. Datta (Author):—I have great pleasure to introduce my paper on "Development and application of Village Cement and High-silica Portland Cement for the construction of concrete roads", a subject which, I hope, will be of some interest to you. At the Roads Congress of 1937 at Lucknow, I had said that for the rapid development of concrete roads in India we wanted cement at cheap cost, cheap transport cost of road making materials, and a cheap method of construction which I described, in which we used bricks or stone boulders in the lower part of the crust, thereby reducing the cost. I declared also on behalf of the Dalmia Cement Companies that after the construction of cement factories at Dehri-on-Sone, etc., the price of cement would be reduced to Rs. 25 or Rs. 23 per ton, f.o.r. factory, for construction work. At that time cement was selling at Rs. 45 to Rs. 50 per ton. I am glad to say today that that part of my forecast has come out to be true. For example, the cost of cement at Calcutta before the declaration of war in September 1939 was Rs. 33 per ton. Of that amount Rs. 10 was the railway freight, and Re. 1 was the lorry charge for delivery at site. The cost of cement f.o.r. factory worked out to Rs. 22 per ton. Though the price of cement was reduced at the factories, the railway freight stood as a stumbling block and did not allow for the expected reduction in the price of cement.

The cost of cement is the main item of cost in concrete road construction. The problem is how we can reduce the cost of cement at the place of consumption. I started and carried out investigation and experiments in the cement laboratory at Dalmianagar for a period of two years. The object was to find out if we could find a cement which will not be inferior in strength in any respect to the present standard but, at the same time, the price could be brought down much lower. I am glad to say that my efforts have materialised, and we can produce cement at a much cheaper cost but with superior strength. Of course, I have discussed this process in my paper. Our aim is to produce cement at a price of Rs. 15 to Rs. 20 per ton at factory and Rs. 20 to Rs. 25 per ton at the place of consumption. How that has been made possible, I have discussed in this paper.

Experiments have shown that when we add 25 per cent to 50 per cent of clay clinker to Portland cement clinker and grind the same with a small percentage of gypsum to a fineness of cement specification, we get a cement which is not only much cheaper but also superior in strength with age than ordinary portland cement. I shall show you one of the briquettes that I tested in connection with that. (Exhibit Shown.) This briquette contains 3 parts of standard sand and one part of cement composed of 65 per cent of cement clinker and 35 per cent of clay clinker and 5 per cent of gypsum. Clay clinker is nothing but ordinary brick *jhama*. We have got thousands of brick-kilns throughout India, and every brick-kiln is producing *jhama* or vitrified bricks in very large quantities. In this particular case we took 35 per cent of *jhama*, 65 per cent of cement clinker and 5 per cent gypsum. The result was that in a period of about 4 weeks we got a strength of 830 pounds per square inch as the tensile strength. In this there is one part of cement, the cement made by mixing 65 parts of cement clinker and 35 parts of vitrified bricks with 5 per cent gypsum (by weight of cement clinker). We took that cement as cement and 3 parts of standard sand by weight. We allowed the briquette to set in water for about 4 weeks and after that we tested the strength.

We got a strength of 830 pounds in that case, a figure which is 25 to 40 per cent higher than that for ordinary portland cement.

As regards the cost, that works out cheaper. We have got thousands of brick-kilns throughout the length and breadth of India, producing *jhama* bricks, and the cost of *jhama* is very cheap. It varies between Rs. 5 to Rs. 10 per thousand cubic feet, and they weigh about $3\frac{1}{2}$ tons, taking the weight of one brick as approximately 8 pounds. The cost of the clay clinker is Rs. 1-8-0 to Rs. 3 per ton. If we take the cost of grinding of the clay clinker to cement specification as Rs. 2 or so per ton, the cost per ton including the cost of grinding comes to Rs. 3-8-0 to Rs. 5. Taking the cost of bagging at Rs. 3 per ton, the total cost comes to about Rs. 8. At any important centre of consumption, where we have got no cement factory nearby, we make the high-silica portland cement by mixing 2 parts of cement clinker and 1 part of *jhama* with 5 per cent gypsum, we get cement which is 25 to 40 per cent stronger than ordinary portland cement.

As regards cost, take the case of Calcutta. In Calcutta the present price of cement is Rs. 36 per ton. If we take 2 parts of cement, then 2 into Rs. 36 comes to Rs. 72, and one part of *jhama* at Rs. 8; then Rs. 72 *plus* Rs. 8 equals Rs. 80, which divided by 3 comes to Rs. 27 per ton, as against Rs. 36 per ton for portland cement. From our experiments we have seen that we can add even 50 per cent *jhama* or vitrified bricks with the cement clinker, that is half cement clinker and half *jhama* with 5 per cent gypsum, which, according to the figures that we shall find in this book gives a strength of 598 pounds per square inch in about 4 weeks, which is much above the British Standard Specification. It means that we take the material according to the price at Calcutta, Rs. 36 for cement, Rs. 8 for *jhama*; then Rs. 36 *plus* Rs. 8 equals Rs. 44, divided by 2 comes to Rs. 22 per ton. That means that at Calcutta we shall be able to produce cement at Rs. 22 per ton as against the price of Rs. 36 per ton for portland cement which is now reigning.

In European countries pozzolana portland cement is used, which is considered superior to ordinary portland cement to resist the action of chemical agents, fire, sea water, etc. In Germany, Trass, which is a kind of pozzolana, is used in cement. There are two brands of Trass cements in the German markets now. One consists of 70 parts of cement and 30 parts of Trass and the other 50 parts of cement and 50 parts of Trass. In Italy also pozzolana is used with cement for similar purposes as described before, and there is a brand in use called "Blended volcanic ash portland cement." In France there is Gaiza cement on that line. The proportion of Trass cements recommended in Germany are as follows:

(*i*) High-lime portland cement	..	66
Trass.	..	34
(*ii*) Low-lime portland cement	..	75
Trass.	..	25
(*iii*) Portland blast furnace cement	..	80
Trass.	..	20

The amount of Trass that is added to the cement varies according to the lime content of the cement. In all cases it is said that the Trass or pozzolana, that is added, is burnt a second time and ground. By burning a second time the silica and pozzolana become more active to combine with the free lime of the portland cement in the presence of water to form compounds of silicate and aluminate of calcium. Our clay clinker

or *jhama* is already burnt to fusion ; I class it as artificial super-pozzolana, and it is very active in its combination with the free lime of the cement. It is for this reason that we get a much higher strength by adding our super-pozzolana or *jhama* to cement than those found by adding Trass, pozzolana, or other kinds of materials like Santorin earth, etc. In order to get super-pozzolana, simply burning of clay will not do; it must be burnt to fusion and produce the vitrified clinker known as *jhama* in the case of overburnt or fused bricks.

At present we have got about 20 cement factories in India. With our new arrangement, we can easily start 20 more factories in important centres of consumption and away from these cement factories, and we can get a supply of cement at much cheaper rates in all important centres of consumption. I am glad to inform you that the Dalmia group of cement factories have already taken up this matter in hand, and they will probably be setting up some more cement factories at different centres of consumption. In Italy, silica cements are being extensively used in roads as published in one of the issues of "Indian Roads".

So far I have referred to silica cement. Now coming to the first part of the paper, namely, "village cement" for highway construction, I say that for places far away from cement factories, where the price of cement comes out to be very high on account of the cost of transport, it becomes necessary to fall back upon "village cement". It is a mixture of lime and clay in the proper proportions; usually 2 parts of lime and 1 part of clay by weight, burnt to fusion in some lime or brick-kiln locally available. That gives a hydraulic cement or lime according to the nature of burning. These cement clinkers are to be ground with artificial pozzolana or *jhama*, preferably with a small percentage of gypsum, if that is available.

Last month I was on a construction work in Assam and there the price of cement was Rs. 49 per ton. I tried to find out if I could manufacture my own cement giving at least half the strength. I have made arrangements for the same and the price works out to Rs. 18 per ton there. An order has been placed with some lime-kiln owners to supply hydraulic cement clinkers and lime at a cost of Rs. 16 per ton. Grinding cost will be Rs. 2 per ton. In all, the price will come to Rs. 18 per ton in place of Rs. 49 per ton for portland cement. This "village cement" is expected to play an important part in highway construction, especially in places far away from cement factories. I have brought for your inspection samples of different cements, with which I have made the tests and the results of which you will see at the end of the paper. In one case I mare tests of silica cement with vitrified bricks which I got from Dalmianagad; the next test was made with cement containing vitrified bricks obtained from Dehri-on-Sone ; the next with vitrified bricks or *jhama* from Calcutta ; I also made a test with vitrified bricks obtained from Cawnpore. The sample packets which I am placing before you contain cements prepared with Cawnpore *jhama*. The first one contains 75 per cent cement clinker and 25 per cent *jhama ;* the second one contains 65 per cent cement clinker and 35 per cent *jhama* ; the third one is 50/50. In the first case we get a strength in about 4 weeks' time of about 700 pounds per square inch, in the second case 800 pounds per square inch, and in the third sample we get about 600 pounds per square inch. According to the British Standard Specification, we want in 3 days 300 pounds and in 7 days 375 pounds per square inch. In each of the samples which I have brought, we got not only

that, but also about double the strength required with time. That will prove that we can manufacture our cement by taking the cement clinker or cement from any of the factories and start factories at Bombay or Calcutta or Madras or elsewhere; we get the local clay clinker or *jhama* from the brick-kilns and make a mixture of different proportions. Supposing we follow the proportions followed generally, namely, 70/30 and 50/50, then the cement that we shall produce will be higher in strength than the Portland cement with age. This proportion, or 65/35, or 70/30 will give a cement which is 30 to 50 per cent stronger than portland cement. The fourth packet contains *jhama* dust, ground to cement specification. It is rather a blackish sort of thing; when you mix it with cement it makes cement darker. The fifth packet contains village cement made by grinding 75 per cent press-mud clinker, (which is made by burning to fusion press-mud of sugar factory containing 2 parts of lime, 1 part of mud approximately) 25 per cent cement clinker and 5 per cent gypsum We made lumps of the press-mud, burnt the same in lime-kiln and some part of it was fused into clinker. I took 75 per cent of that clinker, 25 per cent of the cement clinker with 5 per cent gypsum and ground these to cement specification in the laboratory and passed the cement through 170 mesh. With this cement one part and sand 3 parts, by weight, the test gave us a strength of 670 pounds per square inch in one month. Even here we got a cement which is as strong as, or stronger than, the ordinary portland cement, because in the case of the ordinary portland cement available in the market in very few cases shall we find the strength to be more than 670 pounds, per square inch. I am also laying before you some of the briquettes which were tested to that strength.

There will be many who will say "What you say is not reliable". I say, here are the things; the briquettes, the samples of cement, etc I give you the recipe You test the thing and you will be satisfied. The stuff that you see here is the first product of "village cement". When we mix the lime and clay and burn the mixture at low temperature we do not get the full result. If the mixture is fused, then we get cement clinker, and from that we get the colour and other things Where the mixture is not fused, we get the stuff of which I have a sample here. This is really what we can call cement of the Roman cement specification. Roman cement usually contained about 40 per cent lime and 60 per cent clay; that used to be burnt at about 900 degrees Centigrade. Now this sample also will give you a strength, but not to the same extent as the fused clinker or the clinker which is mixed with portland cement.

I shall welcome your valuable suggestions in this matter, and shall be glad to reply to any questions that you may be pleased to put.

Mr. N. V. Modak (Chairman) :—The paper is now open for discussion.

Nawab Ahsan Yar Jung Bahadur (Hyderabad-Deccan) :—The paper has been very interesting I wish the author had given us correct idea about the analysis, and informed us whether the figures Rs. 27 and Rs 22 were cost prices or selling prices. I think what is exactly required is a chemical analysis of the *jhama*. We are also kept in the dark about the chemical contents of the Pozzolana, which the author has referred to in his paper. The author should put up qualitative and quantitative analysis of the Pozzolana in the "village cement" that has been made by him.

The author quoted Rs. 18 and Rs. 49 as the prices of the village cement in Assam. Are these cost prices or selling prices? Rs. 49 evidently seems a selling price; but is Rs 18 also selling price?

We all know that in the mixture of lime with cement, fine grinding of ordinary lime is required. I have constructed some roads with cement in which the proportion of lime is very high. Many of the members here have seen these roads, which were constructed 7 or 8 years ago and are still in good condition. I think we all agree that the strength of the cement is simply due to fine grinding. Nowadays, the normal cement is ground much more finely than it used to be about 30 years ago. If lime and baked clay are ground to the same extent as the ordinary cement is done, I am absolutely certain that the product will be fairly strong. Of course, experiments have to be carried out and detailed tests recorded.

The author, has referred to fusing. We are not informed about temperatures used in fusing. This is another point on which we require more information. I think it is not possible to fuse cement clinker in ordinary kilns. One must have special kilns for the purpose, as cement clinkers are probably prepared at 2000 degrees Centigrade. If we wish to construct cheaper roads we should grind some of the limes available in different places in India and mix them with cement. Nothing will stand the heavy cart traffic except cement concrete roads. Probably the one suggested by the author may be good for village roads with light traffic. I have made several experiments in this direction, and have come to the conclusion that if we use 1 of Cement 1 of lime and 5 of sand and 8 of aggregate, we will have a fairly strong road. This has been tried by me for certain roads in Hyderabad and they are being used regularly by light traffic for the last 7 or 8 years.

Mr. N. Das Gupta (Calcutta) :—If I have correctly understood the interesting paper presented by Mr. Datta, some quantity of "village cement" was manufactured at the Dalmianagar Cement Factory at his instance and the product as described by him was found to be quite satisfactory. The question now arises whether such cement can be manufactured at villages without plant? The main difficulties, which appear to me as insurmountable, will be to reach the very high temperature of calcination necessary for manufacture of portland cement and to crush the clinkers to 200 mesh particles. If this cement can be manufactured in cement factories, the cost of the so called "village cement" will be more than that of the portland cement, because of the difference in cost of the limestone and quicklime.

The next question that I want to ask the author is whether this village cement is nothing but hydraulic lime obtained by burning impure limestone such as *kankar* in a lime kiln and crushing it to powder as, this is not slakable like pure lime. Like cement, this sets in water and is used for making mortar for underground structures. While working in the Raipur Vizianagaram Railway construction, I have seen such hydraulic lime being used for construction of coursed-rubble masonry wells, as well as piers and abutments of a large bridge which consisted of 20 spans of 100 feet girders. The mortar was found to be very strong and to set under water. I personally think that the term 'hydraulic cement' given by Mr. Datta should not be used as all cements set under water and are, therefore, hydraulic.

As regards high silica cement, I may say that the process of manufacture is not clear, and that the reactions involved have not been furnished by the author. Clay is principally alumina (Al_2O_3) and only contains CaO and MgO in some proportions. If this clay be burnt, I believe the resulting product is alumina, and by mixing burnt clay dust with cement we are really having high-alumina cement and not high-silica cement. Mr. Datta would have done well if he had furnished in his paper approximate chemical reactions involved in the manufacture of this high-silica cement. May I also enquire of Mr. Datta, as he is an expert on cements, what are the tests for silica and alumina and how can one be identified and separated from the other ? What is the average composition of clay he recommends for the manufacture of such cements ?

Mr. S. B. Joshi (Bombay) :—I was myself in search of some method of manufacturing cement for roads at the door of the villager because that would be a cheaper solution to the problem of village roads. The Indian National Planning Committee at present are considering the problem of housing the labouring class. It then occured to us that some method of manufacturing cheap cement should be found out for it, and I referred to Mr. Kynnersley as to whether there was a possibility of finding some such method. His answer was no. Now Mr. Datta has given us some practical suggestions wherein he says that there is likelihood of success in getting such cement. I think it would be a good substitute for the ordinary deteriorated lime. The cement that Mr. Datta suggests is nothing different from the hydraulic lime mortars that have been used on some of our dams. *e.g.*, in the Bhatgar and Tata dams. We get hydraulic limes of this type in Deccan. Hydraulicity can be increased artificially by admixture of *Surkhi*.

I can understand that the cement, Mr. Datta is going to manufacture, will have better qualities than the Portland cement that we get in the bazar, but the time that he will take to attain the maximum strength will be of about 2 years

, We are preferring rapid hardening cement in order to allow the traffic to use the road as early as possible. So this time factor will come in the way of using "village cement" on all roads. I do not think there is any possibility of competition between the present cement and Mr. Datta's "village cement". Both will have their own fields.

The only difference that we can find between the hydraulic lime mortar used on the Bhatgar and Tata dams and the cement that Mr. Datta proposes is that in the latter case, there are two burning operations. Bricks made of the mixture of slaked lime and clay are burnt at high temperature in Mr. Datta's method. This ensures a better mix with the clay.

I endorse the suggestion that mixture of lime and cement have some good qualities, for instance imperviousness. I think that the ordinary cement has got qualities whereby the original nucleus has got a tendency to contract while the lime has got qualities whereby it has a tendency to expand to an infinitesimal extent so that the mixture of the two makes it impervious

Rai Sahib Lala Fateh Chand (Bijnor) :—I congratulate the author of this interesting paper which requires serious consideration and careful

examination by this Congress. If the experiment is successful, it will have far reaching effects in accelerating the progress of roads in India, and particularly in developing village communications. Mr. Datta has made experiments with only 3 proportions. I would enquire of Mr. Datta whether he has tried this cement, or hydraulic lime which name I would prefer to be given to it, with 1 : 6 proportion that we do in the case of ordinary cement mortar used in lieu of lime mortar, and if so with what result ? Did he use 1 : 3 : 6 mix for concrete and compare it with the results given by the Portland cement similarly mixed ? If so, what is its strength ? I think the cost given by Mr. Datta is much lower than what it will actually work out to be when the experiment is seriously taken up. The cost of burning lime in the manner he has suggested, will naturally be much higher, because of the cost of mixing and breaking in addition to that of burning. It may be possible to have the results compared with the help of the testing machinary erected in Dalmianagar, or in any one of the cement factories. I think the cost will be much higher according to the methods suggested by Mr. Datta. The methods adopted in the large scale cement factories are very economical, and those suggested by Mr. Datta are not likely to be able to compete with them. By this I do not mean to discourage the author at all. He has done a great service by opening a discussion on this point, and I think the matter requires further investigation by the Government of India, or by the Indian Roads Congress. Experiments should be made at the Alipore Test House, or at Dalmianagar to find out the strength that this hydraulic lime or cement acquires in different proportions. I would like to suggest that everything should be done to make this experiment a success. Mr. Datta has given us some suggestions to make the present Portland cement stronger than what it is. I have seen that in Cement Factories the proportion of mixing the various materials is very efficiently controlled. If, after the whole thing has been prepared, it is found that the proper proportion is missing, they throw away the whole stuff and add or take away that little thing that is either wanted or is in excess as the case may be. I think it is difficult to maintain the proportion if the process suggested by Mr. Datta is adopted, as in that case it would be difficult to control proportions. I think we can add more silicate in the Cement Factories more easily than if prepared in the manner suggested by Mr. Datta The whole thing, as I have said, requires thorough investigation, even if the resulting stuff is not as good and as cheap as the cement produced in the factories.

Mr. T. Campbell Gray (Madras) :—As you are aware, high-silica cement is not new, though its use has been mainly confined in America and elsewhere to concrete constructions in sea water. Mr. Datta's paper (Appendix I) furnishes figures of tensile strength at 3 days, 7 days and 28 days, but these do not appear to be Alipore Test House or other officially verified results and do not go far enough. Results of official tests under each of Mr. Datta's references at 6 months, 12 months and 2 years are required to make sure there has not been retrogression.

A vast number of experiments have been carried out all over the world with a view to obtaining increased strength from Portland Cement by the addition of various materials in powder or liquid form and I think it would be dangerous to draw any conclusions from the results of Mr. Datta's interesting experiments until full test results are available bearing

the certificate of the Government Test House or other recognized testing laboratory.

Mr. A. Lakshminarayana Rao (Madras) :—I request the author, Mr. Datta, to supply information on the following questions :—

(1) What is the actual cost of the "village cement" per hundred-weight ?

(2) What is the maximum quantity of "village cement" manufactured at a time by the author ?

(3) (*a*) Was the "village cement" used for construction purposes ?

(*b*) If it was used, on what works was it used ?

(4) Was the cement powdered in a grinding mill up to British Standard Specifications and was the product chemically analysed ?

Mr. Syed Arifuddin (Hyderabad-Deccan) :—I must thank Mr. Datta for having brought the problem of making some kind of cement or hydraulic lime in districts to the notice of the Roads Congress.

As far as I understand, his "village cement" is based on the theory that at least a portion of the lime will combine with silica and alumina if the mixture is burnt even at a much lower degree than it is done in the case of cement. Perhaps he assumes that 800 to 900 degrees Centigrade will do. Secondly, the lime which is not combined with silica or alumina in the kiln will combine with silica or alumina, which he expects will be in the active state, in the presence of water.

On page 3 of his paper, he has given the strength as 1 lime and 3 *soorkhi*. This is really very high. I should like to know whether it was the ordinary lime or his "village cement". If it was ordinary hydraulic lime the high strength is due to the *soorkhi* being over-burnt. The point will then arise as to why we should burn slaked lime and clay. It will be enough if we burn earth to form clinkers and then grind it to fine powder to be mixed with lime. I request Mr. Datta to clear these two points It would have been very useful to us if it was possible for him to give the result of the detailed tests of his "village cement" with different proportions of sand and *soorkhi*, as he has done for high-silica cement. I would request him to carry out these tests in his laboratory and inform all the brother members of the Congress individually of their result. We will all be thankful to him for that.

It seems to me that there are two main difficulties in the way of such cement being made locally at a number of places. One is the uncertainty of getting the right class of hard clinkers from ordinary lime-kilns and the other is the grinding of these clinkers to palpable powder, without which combination cannot take place between lime and active silica in the presence of water. The portion which is not palpable powder simply acts like aggregate. Such fine grinding of hard clinkers cannot be done in a mortar grinding machine. For large output, sufficiently high power grinders will be required The problem of suitable kilns and attaining the necessary temperature will also have to be investigated and solved. If this idea proves successful after further investigations,

it certainly deserves our careful thought as to how it can be put into practice and where its use will be justifiable, taking the cost and other things into consideration.

With regard to high-silica Portland Cement, I shall be obliged to the author if he will kindly inform us as to how he burnt the clay into clinkers; what was the maximum temperature reached in the kiln; and what were the nature and the chemical analysis of the clay.

Mr. S. K. Ghose (Bihar) :—I have a few questions to ask of Mr. Datta in connection with his paper. I would also request you to help him in getting his ideas put into a more practical form. If cement roads are to be built in villages, then the "village cement" will have to be manufactured by the villagers themselves. I do not expect that many of our engineers will go to the villages to do the work for the villagers. So, I should like to suggest to Mr. Datta that he should publish the details in this paper in Hindi also.

It would have been better if Mr. Datta had furnished us with the details of the analysis. There are a few inaccuracies and omissions in the tabulated results. He should also have mentioned in his paper as to what sort of testing machine he used in his experiment, so that it would have helped us in checking his results. Apparently his cement is not going to be a rival to Dalmia's cements as the poor villagers will not have that necessary finance which is required to have the machinery for grinding the cement to the fineness that is obtained by the factory-manufactured cement. Mr. Datta has also not mentioned in his paper about tests on the soundness of the "village cement". Of course, I do not want Mr. Datta to discontinue his experiments, but rather he should pursue them further so that we may test the results of his experiments individually and let him know of what we think about them in a future session of the Congress.

Mr. N.V. Modak (Chairman) :—Does anybody else wish to speak on the paper? (After a pause). As nobody wants to speak further on the subject, and before I request the author to reply to the numerous questions asked by the various speakers, I wish to add a few remarks of my own on the paper.

I have read with great interest Mr. Datta's paper, and really he deserves congratulations of the Congress for having suggested to us a way by which we can think of reducing the cost of our roads. Of course, all the information therein contained, although taken for granted as being correct, cannot be said to be useful and advantageous at all the places. There might be some places where it would be possible to have the high-silica cement, as the author calls it, manufactured at the site at cheap cost. It may not be possible to do so everywhere, because after all it is a question of mass production which requires proper supervision and skilled labour. Then there is the question of competition. If the 'village cement' can be manufactured at cheap cost, then the other cement companies would probably reduce the cost of their cement.

It was suggested that the Congress should request the Railway authorities to reduce the freight on cement whenever it is required for road purposes. I hope this point will be considered by the Roads Congress.

Mr. Datta has suggested two things. The "village cement" can be manufactured at places wherever there are favourable circumstances at cheap cost and thereby it will be possible to compete with the Portland Cement. He has given us an example of how this was done in Assam. If this is possible everywhere, then the cost of road construction will go down considerably in India, and then we will be able to make a good deal of progress in that direction. However, what is really needed now is that Mr. Datta should give us more data and bring his paper within the bounds of practical politics. With the materials now available, I do not think any engineer will be able to achieve tangible results.

I hope that Mr. Datta will continue his efforts undaunted in this direction, so that he will be in a position to give us next year fuller particulars as to the way in which to reduce the cost of cement.

I now request Mr. Datta to answer the various queries

Mr. A. K. Datta (Calcutta):—I must thank Nawab Ahsan Yar Jung Bahadur for his welcome criticisms. With reference to the queries and observations made by him, I give below the required information.

The selling price of cement at Calcutta before war broke out, in September (1939), was Rs. 32/- to Rs. 33/- per ton. The railway freight paid by the different cement companies, selling cements at Calcutta, per ton of cement from the Factory to Calcutta was Rs. 10/- to Rs. 11/-. The lorry charges for delivery of goods from godown to site, and the godown charges come to Rs. 1/8/- per ton. Commission to selling agents—usually Rs. 1/8/- per ton; cost of bags, 20 per ton of cement, @ As. -/2/6 each—Rs. 3/4/-; advertizement charges, and packing and despatching charges come to at least Re. 1/- per ton. These make a sum total of Rs. 17/4/- to 18/4/- per ton. Deducting this cost from the selling price of cement Rs. 32/- to Rs. 33/- per ton, the cost of cement at factory comes to Rs. 14/12/- per ton. If we analyse the cost of raw materials, labour, coal, power consumption, depreciation, interest on capital, etc. we shall find that there is not much margin of profit in that selling price of cement. The figures of Rs. 27/- and Rs. 22/- per ton are selling prices on similar lines with a small margin of profit. On account of the competition between the rival groups of cement companies, the price of cement came down to such low levels.

He wanted to know the analysis of *jhama* and chemical contents of Pozzolana. I got analysed the *jhama* bricks of Calcutta, Dalmianagar and Cawnpore. I have analysis with me of clay of different places. At Calcutta it was as follows :—

SiO_2	..	67.83	per cent.
Al_2O_3	..	18.87	per cent.
Fe_2O_3	..	7.63	per cent.
CaO	..	2.80	per cent.
MgO	..	2.44	per cent.
		99.57	

The *jhama* of Dalmianagar contained a higher percentage of silica. The composition of clay varies from place to place, usually we get for normal clay :—

SiO_2	..	66.5	per cent.
Al_2O_3	..	18.2	per cent.
Fe_2O_3	..	8.4	per cent.
CaO	..	0.4	per cent.
MgO	..	0.3	per cent.
Co_2 and water	..	5.1	per cent.
Alkalies	..	1.1	per cent.
		100.0	

Natural Pozzolana* is a naturally burnt earth of volcanic origin found at Pozzuli, near Visuvius and in other parts of Southern Europe.

It is found in the form of powder, more or less coarse in grain, of a brown colour sometimes passing into red, grey, yellow and white. They aré clayey earths containing 80 to 90 per cent of clay with a little lime and small quantities of magnesia, potash, soda, oxide of iron or manganese.

In the Pozzolana, used in pozzolanic cement in Italy, the approximate composition of Pozzolana was as follows .—

SiO_2	..	46	per cent
Fe_2O_3	..	11	per cent.
Al_2O_3	...	22	per cent.
CaO	..	10	per cent.
Loss in ignition	..	10	per cent.
		99.0	

The chemical contents of Pozzolanas also differ from place to place considerably. *Jhama* is artificial Pozzolana as I described in my paper.

My experiments on "village cement" were first made with different proportions of mud and slaked lime. Weight of same volume of mud was double the weight of the same volume of lime. My experiments were first made with :—

(1) slaked lime	..	1	and	mud	..	1 by volume,
(2) slaked lime	..	2	and	mud	..	1 by volume,
(3) slaked lime	..	3	and	mud	..	1 by volume,
(4) slaked lime	..	4	and	mud	..	1 by volume,
(5) slaked lime	..	6	and	mud	..	1 by volume,
(6) pressed mud	..	1	and	mud	..	1 by volume,
and (7) lime	..	1	and	pressed mud	..	4 by volume.

* Ref: Chemistry of Cement & Concrete, by Lea & Desch.

Lime and mud were mixed, made into bricks and burnt in brick or lime-kilns.

Analysis of pressed mud of sugar factory was approximately as follows :—

		Percentages excluding loss.
SiO_2	.. 10 94	19 per cent.
Fe_2O_3 & Al_2O_3	.. 5.54	9.6 per cent.
CaO	.. 37 79	65.7 per cent.
MgO	.. 2.84	4.95 per cent.
Loss	.. 43.70	

The limits of composition of portland cement are as follows :—

CaO	.. 60 to 67 %;	SiO_2	.. 17 to 25 %
Al_2O_3	.. 3 to 8 %;	Fe_2O_3	.. 0.5 to 5.5 %
MgO	.. 0.5 to 5.5 %;	Na_2O & K_2O	.. 0.5 to 1.3 %
		SO_3	.. 1 to 3 %.

For the preparation of "village cement" to the portland cement specification, we require 2 to 2½ parts of lime and 1 part of clay roughly. Where arrangement for chemical analysis can be made the proportion can be adjusted according to the analytical results of the local materials.

As regards the price of "village cement" in Assam, the analysis gave the figure Rs. 18/- per ton as the cost of production. Rs. 49/- is the selling price of portland cement there.

Cement clinkers are usually burnt at temperatures between 1200 to 1400 degrees Centigrade in modern rotary kilns I agree with Nawab Ahsan Yar Jung Bahadur about his observations on fine grinding of lime and clay mortar. By clay, I presume, he meant well-burnt clay. Ordinary lime-clay mortar will give very little strength. When clay is burnt, the silica and alumina become active and enter into combination with lime in presence of water to form compounds of silicate and aluminate of calcium. The importance of burning and fine grinding is very great. His experiments on lime-cement concrete road construction prove that this method of construction can be safely adopted for cheeper concrete road constrnctions 1 cement, 1 lime, 5 sand and 8 ballast proportion of concrete gave excellent results in his trials and those roads are standing for the last 7 to 8 years. Under such circumstances I am quite confident that "village cement" with certain percentage of portland cement mixed with it will give very good results *in roads construction.* When we examine the constituents of cement, *viz,* limestone and clay—finely ground and mixed and then burnt in rotary kilns, limestone loses CO_2 and is reduced to lime; Clay, on being burnt becomes *jhama* at high temperatures—both enter into a combination. In lime and *soorkhi,* we have got the same ingredients as in cement. If we take lime and well-burnt *soorkhi* and grind the same to cement specification with a small percentage of gypsum as in the manufacture of cement, the resultant mixture will set like cement with a little

age in presence of water In hydraulic lime manufacture, if we burn nodules or *kankar* at high temperature, adjust the proportion of lime to silica and alumina by adding well-burnt *soorkhi* or *jhama* dust ground to cement specification, with a small percentage of gypsum, we shall get the resultant mortar setting like cement with time. There is lot of field for research on these lines.

Now I come to the comments of Mr. N. Das Gupta. At the very beginning I have said that the manufacture of "village cement" should be taken up in places far away from the cement factories where the cost of cement comes up very high on account of the freight charges. In my reply to the observations of Nawab Ahsan Yar Jung Bahadur, I showed that out of Rs. 32/- per ton, the selling price of cement at Calcutta, Rs. 17/4/- per ton came as Railway freight, packing charges, commission to agents etc. and Rs. 14/12/- as the cost of production and profit. Now if we consider places still further away, we shall find that 2/3rds of the rate is due to those items and only 1/3rd of the rate is due to the cost of production. Thus comes the importance of the "village cement", which eliminates practically the major part of those items of cost. Besides, in the production, we do not aspire to get the high initial strength of the cement as that of portland cement, but with age we shall approach those results. For grinding, we can easily set up small Disintegrators or Grinding mills and grind the "village cement". I agree with Mr. Das Gupta that it will be difficult to grind the 'village cement' clinkers to cement specification unless small ball mills are set up.

As regards burning and grinding *kankar*, I have dealt with that before. As regards chemical action, this is pozzolanic action. Here we get the formation of silicate and aluminate of calcium in the presence of water and it sets hard like cement with age. Referring to Encyclopædia Britannica—page 110, under heading "Cement" it is given "Pozzolanic cement—Lime, in presence of water readily combines with the silica in the active state and forms Calcium silicate similar to that of portland cement. Various natural and artificial materials such as, Pozzolana, Trass, Kaiselghar, Pumice, Tufa, Santorin earth, granulated slag, etc., contain active silica and when the cost is low, they make a useful addition to the lime mortar."

The process of manufacture of high-silica cement is to grind cement clinker, *jhama* and gypsum in required proportions to a fineness of cement specification. As regards information about chemical analysis, I should suggest to Mr. Das Gupta to read any practical chemistry on analysis of cementing materials. He can refer to "A Handbook for cement works chemists" by Francis B. Gatehouse, published by C. Griffin & Co., Ltd. As regards composition of ordinary clay suitable for such cements, he can take the average analysis already given.

The observations of Mr. Joshi are very interesting. His reference to the hydraulic lime mortars used in Bhatgar and Tata Dams is also interesting. In the manufacture of cement we want 3 things—proper proportioning, burning at high temperature, say between 1200 to 1400 degrees Centigrade and fine grinding to pass through a screen of 170 mesh per inch leaving a residue of 3 to 4 per cent. For proper proportioning, we can use lime-stone and clay—ground to slurry or dust—as done in cement factories by the wet or dry processes. We can use lime and clay and mix up the same either dry or wet. We can take lime and *soorkhi* ground finely and

mixed. As long as the proper proportioning is there, we shall get cement from every mixture, so long as we burn it at suitable temperatures and grind the clinkers to cement specification with a little gypsum. The deeper we go into this subject, we find it more interesting and less difficult to manufacture cement. From analytical results of Trass, a kind of Pozzolana available in Germany and our *soorkhi*, we find similar constituents and similar results.

Now-a-days Trass is usually very finely powdered and is used with lime in Germany. The following results with lime-trass mortars will be found very interesting.

***Effect of fineness of grinding of Pozzolana**

1 : 4 : 15 lime-Trass-graded sand mortars.

Percentage residue on 170 mesh screen.	Strength—lbs. per sq. inch.			
	Bending.		Compression.	
	28 days.	1 year.	28 days.	1 year.
43	183	372	341	1190
14 5	269	475	500	1280
3	306	480	690	1460

In Table XLVIII*, we find,

Effect of Pozzolana-lime ratio on strength of mortars.

Pozzolana.	Mix proportion (weight).			Tensile strength—lbs. per sq. in.			
	Hydr Lime.	Pozzolana.	Sand.	7 days.	28 days.	90 days.	1 year.
Shell ..	1	1	6	107	207	341	521
	1	2	9	133	322	459	560
	1	4	15	203	371	514	533
Trass ..	1	1	6	213	361	448	482
	1	2	9	225	390	420	500
	1	4	15	238	366	415	437

* Ref. Chemistry of Cement and Mortar, by Lea & Desch, page 261.

As regards the question of setting time, we see from the Table above that, with time, the strength is very greatly increased approaching that of portland cement. If we add a small quantity of cement, say 12 to 20 per cent of the weight of lime *soorkhi* or Pozzolana mortar, the strength is greatly increased in a very few days.

I thank Rai Sahib Fateh Chand for his welcome criticisms. If he refers to the Table reproduced above about the strength with Lime-Trass mortars he will find the strength with Lime-1, Burnt Trass-4, Standard sand-15 mortars at ages 7 days, 28 days, 90 days, and 1 year, as 238, 366, 416, 433 pounds per square inch. Hard-burnt clay, finely ground, will give better results than Trass. Thus we find that we can use much weaker proportion than he mentioned with satisfactory results.

The German Standard Specification for Trass, according to Chemistry of Cement and Mortar by Lea & Desch, is :—

"Fineness—Residue on 30 mesh per c.m. screen
—not greater than 20 per cent.

Combined water—not less than 6 per cent."

As regards his observations about "village cement," I agree with him that the cost of production will be higher than the cost of production in portland cement factories, but I have said while introducing my paper, that at places far away from cement factories, where the transport cost of cement will run up very high, the manufacture of "village cement" can be taken up with very great advantage. I mentioned the case of Assam at Chhatak, where the present cost of cement was Rs. 49/- per ton and the analytical cost of "village cement" came up to Rs. 18/- per ton only. I agree with Rai Sahib that this matter requires further investigation by the Government of India or by the Indian Roads Congress.

The reason as to why the addition of *jhama* or Pozzolana increases considerably the strength of the portland cement, I have described in my paper and also in replies to the queries just now.

Mr. Campbell Gray enquires about the strength of the silica-cement mortar with age as 3 months, 6 months and 12 months. It will appear from the Table reproduced above about the strength of lime-Pozzolana mortars at ages of 7 days, 28 days, 3 months and 1 year that gradual increase in strength takes place. With Pozzolana portland cement also we get similar results.

Regarding Mr. A. Lakshminarayana Rao's questions :—

(1) The actual cost of "village cement" per ton.—It will vary from place to place, and will be dependant on the cost of lime, rates of labour, cost of fuel and coal. At Chhatak in Assam, it worked out at Rs. 18/- per ton. At Jairamnagar near Bilaspur (C. P.) it worked out at Rs. 14/- per ton, as the labour is very cheap there—As. -/2/- for *Reza* and As. -/3/- for coolies per day of 8 hours and cost of coal at Rs. 6/- per ton only.

(2) Maximum quantity of village cement manufactured at a time.—I burnt a lime kiln load at a time at Dalmianagar. Part of the product comes out as hydraulic lime and part as cement clinkers.

(3) We used the hydraulic lime in the place of ordinary lime in some brick-work in Dalmianagar.

(4) The cement clinkers were powdered in the Laboratory ball mill and ground to cement specification—passing 170 mesh per inch with 3 to 4 per cent as residue.

The pressed muds from which bricks were made were previously analysed chemically.

Mr. Syed Arifuddin is right in his diagnosis of "village cement". Reference to the strength of lime: *soorkhi* mortar (1 : 3), his observation is that the results are very high. Now these results are from Government Test House, Alipore. If he refers to page 11 (c), he will find the number and date of the Tests. During our visit to Government Test House in February, 1939 (5th Indian Road Congress at Calcutta), we saw the Test results with many other brands of lime. We were informed by the gentleman who was doing the experiments that with lime and *jhama* (1 : 3), he got results as high as 600 pounds per square inch. By burning lime and clay, there is a chemical combination of lime with silica and alumina and by that the lime will acquire hydraulic properties and will set under water. The strength will be acquired earlier than in the other method.

As to his enquiry about the Tests with different proportions of sand and *soorkhi*, I may ask him to refer to the exprments on lime-Trass-sand mortars. I have requested our President, Mr. Mitchell, to give me facility for doing the experiments at Government Test House, Alipore. If I get the facility I may be able to give further information in the next Meetings of the Congress

Mr. Syed Arifuddin is right in his conjecture about the difficulties, *viz*, getting right class of clinkers and secondly grinding, the same to fineness of cement specification. In "village cement," our aim is mostly to produce a cement which is much better than lime but somewhat inferior to cement, *i e.*, half-way between cement and lime I am trying to help a party to start a "village cement" factory at Jairamnagar, (10 miles from Bilaspur), in C. P. The points raised by Mr. Arifuddin are receiving my attention already in the actual execution of works. Here the labour is cheap, limestone available in plenty, say at Rs. 2/- per ton; coal is available nearby and quite cheap, say Rs. 6/- per ton, good clay is available. By burning limestone we shall get unslaked lime, we shall mix slaked lime with mud in *Belchakki*, and make bricks or lumps with the same. These will be burnt in a suitable kiln and then powdered with some percentage of gypsum and brick *jhama*. So I think there will not be much trouble in getting the thing done. We are now looking after a Ball-mill for grinding purposes We may add a small percentage of cement also at the beginning. So the capital outlay in this production will not be high.

As to his enquiry about silica portland cement—about the burning of clay into clinkers, I may inform him that these clay clinkers are nothing but brick *jhama*, obtained from brick kilns. I had mentioned this in introducing my paper. As to the analysis, I have already given these figures in reply to Nawab Ahsan Yar Jung Bahadur. The temperature of fusion of bricks is between 800 to 900 degrees Centigrade.

With reference to the query of Mr. S. K. Ghose about analysis of "village cement", we follow two procedures of approximate analysis.

(1) making cement on Roman Cement Specification,

(2) making cement on Portland Cement Specification.

In the first case, we see that we get in the cement about 40 per cent lime and 60 per cent clay, whereas, in the latter, about 60 per cent lime and 40 per cent clay. It is not always possible to do detailed analysis in producing "villege cement". So what we do, is approximate. We take the approximate analysis of the clay and of the lime and we then base our proportions.

As to the Testing machine used in doing the experiments, I used Aides' standard testing machine of the Dalmianagar cement Laboratory. As to his enquiry about my Testing machine, I may inform him that I made comparative tests in both machines side by side and found similar results. Both machines give accurate results. About the quality aimed at in making "village cement," I have described before.

Regarding soundness of the cement, I may inform Mr. Ghose that it was quite sound like the Portland Cement. I added 5 per cent of gypsum with the village cement clinkers to make the cement sound.

I thank Mr. Modak for his observations. Regarding high-silica cement, there will be no great difficulty in its manufacture. What we want is a grinding Ball-mill, which we can set up in any place and grind *jhama* to cement specification and mix up cement with the same. Where we want it on an extensive scale, we grind cement clinker, *jhama* and gypsum in the grinding mill and produce silica cement. The great advantage of this procedure is that we can store cement clinkers for months in a place without deterioration and whenever fresh cement is wanted it can be manufactured from the cement clinker, *jhama* and gypsum. Thus, high-silica cement factories can be started in all important centres of consumption, such as, Calcutta, Bombay, Madras, Lahore, Ahmedabad, Multan, Dacca, Chittagong, Barisal, etc., etc, with great advantages in road construction and to the public for use in new buildings. It is impossible for the ordinary portland cement, manufactured at great distances, to cope with the locally produced high-silica cement.

I give my whole hearted support to Mr. Modak's proposal that the Congress should request the Railway authorities to reduce the freight on cement, whenever it is required for road purposes.

The venue of War is gradually changing from the West to the East. If India is attacked, the importance of concrete roads, will at once be realised by the Government and the public Again, I thank Mr. Modak for his suggestions and I hope to make further advance in this matter before the next meeting of the Indian Roads Congress.

Experiments have been taken up to find if we can produce the village cement without burning. An advance has already been made in that line. It consists in making fine mixture of lime and hard-burnt *soorkhi* and mixing some percentage of gypsum and cement with it. If these experiments produce the desired results, the production of "village cement" will be easier and cheaper.

PAPERS Nos. A AND B—39

Mr. P. V. Chance (Chairman):—I would request Mr. Walker to introduce his paper A—39 on "Evolution of the thin concrete road in the United Provinces."

Mr. Mahabir Prasad will then introduce Paper B—39 "Repair and maintenance of Cement Concrete roads," by Rai Bahadur A. C. Mukerjee in the absence of the author.

The following papers were then taken as read :—

PAPER No. A—39.

EVOLUTION OF THE THIN CONCRETE ROAD IN THE UNITED PROVINCES.

By

W. F. WALKER, M.C., I.S.E.,

Superintending Engineer, Public Works Department, United Provinces.

In 1919-20, several corners on the Kathgodam to Naini Tal road were reconstructed in cement concrete 1 : 2 : 3½ mix laid 4 inches and 6 inches thick over a good foundation of old road metal. This concrete is still giving good service after 20 years.

In 1926-27, more corners were concreted on the Bareilly-Ranikhet road with a 1 : 2 : 4 mix laid 6 inches thick over a well consolidated road crust 10 inches thick. The cost of this work was Rs. 65/8/- per hundred square feet.

At the same time mile 422 of the Grand Trunk Road at Benares was concreted for 4 furlongs using 1 : 2 : 4 mix laid 9 inches—6 inches—9 inches thick over a ½ inch insulation layer of sand on a good foundation made by the old road. The cost was Rs. 64/- per hundred square feet.

In 1927-28, miles 413, 414, 423 of the Grand Trunk Road were laid in the same way at about the same cost.

In 1928-29, some 10 miles of cement concrete were laid mostly 6 inches thick with thickened edges at an average cost of about Rs. 64/- per hundred square feet.

A small area was laid 4½ inches thick over an old cement-grouted surface at a cost of Rs. 58/4/- per hundred square feet.

In 1929-30, about 4 miles were concreted with a thickness of 9 inches—6 inches—9 inches at a cost of about Rs. 64/- per hundred square feet whilst one mile was laid 6 inches—4 inches—6 inches without any insulation.

In 1930-31, about 7 miles were concreted 9 inches—6 inches—9 inches and 3 miles 6 inches—4 inches—6 inches.

In 1931-32, only 1 mile of thick concrete slab was made and experiments were made with slabs only 2 inches thick.

2. The standard specification in the United Provinces for cement concrete roads constructed before 1932 had been as follows :

Thickness of concrete ..	.. 9 inches—6 inches—9 inches.
Width ..	... 20 feet without any longitudinal joint.

Length of Bay	33 feet,
Camber	Central portion parabolic sloping at 1 in 60 to the sides.
Joints	Spaced laterally at 33 feet and inclined at 60 degrees to the axis of the road.

The ends of the slabs when laid in alternate bays were painted with bitumen.

Foundations	Consisted of the old road bed shaped to proper camber and at least 6 inches thick.
Insulation layer	½ inch of sand.
Mix	1 : 2 : 4 with 1½ pounds of slaked lime per bag batch and 5 to 6 gallons of water.
Laying	This was done on the alternate bay system in 2 courses laid practically simultaneously.
Curing	Done with wet earth for 21 days.
Hardening	Done with silicate of soda P 84 grade. Three coats of 1 : 4 solution applied at intervals of 24 hours after the cement had set and hardened for 24 hours after laying.
Temperatures	Ranged from 80-106 degrees Fahrenheit in the shade.

Upto 1932 some 30 miles of road had been laid to this specification on some of the heaviest trafficked miles at a cost of about Rs. 64/- per hundred square feet. These pavements had carried 2000 tons per day of heavy bullock-cart traffic for 5 years and more without showing any appreciable wear. The maintenance had been less than Rs. 5/- a mile and the riding qualities were excellent. The only drawback was the high initial cost.

Some 6 miles of thinner slabs mostly 6 inches—4 inches—6 inches had been laid and these had given excellent results after two years under heavy traffic and the initial cost was reduced to about Rs. 45/- per hundred square feet.

It was found that in the case of thin slabs the following considerations were of importance:

(i) The foundations must be especially firm and well drained. An old metalled road with a crust at least 6 inches thick forms an excellent foundation.

(*ii*) There should be no insulation to separate the thin slab from the road bed.

An insulation layer of sand may weaken the concrete first laid and, upon drying up, may cause voids under the slab by incorporation of the sand into the concrete and the subgrade. The effects of this are analogous to that of subsidence of the subgrade especially when the slab has thickened edges or a rib in the middle.

(*iii*) Thin slabs should be of uniform thickness. Edges, ends and centres should not be thickened because it is impossible to compact an irregular subgrade.

Even thick slabs often ring with a hollow sound when iron tyred traffic passes over them and this is probably due to items (*ii*) and (*iii*).

(*iv*) Thin slabs should be anchored to the subgrade which should be cleaned by brushing until the interstices between the metal are about $\frac{1}{2}$ inch deep so that the concrete will be well keyed to the subgrade. This transmits the stresses better by making the pavement bear well and evenly and distributes the shrinkage stresses so that hair cracks may develop but larger cracks are not formed.

(*v*) For thin slabs, the greatest care in mixing is necessary. Pockets of poor mix will be fatal because they will be near the surface and will wear into holes.

(*vi*) Very great care is necessary at the joints and continuous construction with expansion joints at about 30 feet intervals is desirable.

* [See Bulletin No. 9 issued from Chief Engineer's Office, United Provinces, Public Works Department, Buildings and Roads Branch.]

3. By 1935, the thinner slab had definitely proved itself to be satisfactory and the concreting of the Grand Trunk Road from Ghaziabad to Bulandshahr with slabs $5\frac{1}{2}$ inches—$3\frac{1}{2}$ inches—$5\frac{1}{2}$ inches was begun and 8 miles were completed.

In 1936, another 15 miles of this road were concreted and the remaining two miles were completed early in 1937. The average cost of the 25 miles of road was approximately Rs. 33/4/- per hundred square feet.

This road is believed to be the longest continuous length of cement ~~concrete~~ road in India and it has a rather interesting history.

A contract had been arranged for reconstructing the road with a coat of stone painted with bitumen and about 5 miles had been completed to this specification. The contractor had to construct the road and maintain it for a period of 8 years after completion and hand it over to Government in good condition after the expiry of the maintenance period.

* *Vide* Note on page 14 (*a*) Appendix II

The contractor decided that it would pay him to construct a cement concrete road rather than a painted road and he was allowed to do this on the condition that he would get no extra payment from Government. The indications are that the change in specification will result in a considerable financial gain both to the contractor and to Government.

In 1936, another 10 miles of 6 inches—4 inches—6 inches or 5½ inches—3½ inches—5½ inches cement concrete were laid and only one mile of 9 inches—6 inches—9 inches.

In 1937, a further 10 miles of 6 inches—4 inches—6 inches or 5½ inches—3½ inches—5½ inches were laid at a cost of about Rs. 38/12/- per hundred square feet and 2½ miles of thinner slab 3 inches—2 inches—3 inches and 2 inches—2 inches—2 inches were laid at a cost of about Rs. 25/12/- per hundred square feet.

In 1938, 11 miles of 6 inches—4 inches—6 inches were laid at a cost of about Rs. 36/- per hundred square feet, one mile of 4 inches—3 inches—4 inches at Rs. 30/8/- and 5 miles of 3 inches—2 inches—3 inches at Rs. 27/12/- per hundred square feet.

In 1939, some 7 miles of 3 inches uniform thickness, 1 mile of 4 inches and 1 mile of 5½ inches—3 inches—5½ inches were laid and it was proposed to lay 9 miles of plain concrete 3 inches thick at a cost of Rs. 22/4/- per hundred square feet in Cawnpore and some 6 miles 3½ inches thick in Lucknow in 1939-40.

It will be seen that we have over 100 miles of cement concrete road of which over 15 miles have been laid 3 inches thick or even less. Some of these thin concrete miles have been in use for 4 years and todate the results have been very satisfactory. The cost has been reduced from Rs. 66/12/- down to Rs. 22/4/- per hundred square feet.

4. Innumerable experiments have been tried whilst making these roads and it has been found that satisfactory results can be obtained using a 1 : 2 : 4 mix laid on good foundations of at least 6 inches of old road crust; no insulation layer should be used but instead every effort should be made to bond the concrete to the subgrade; expansion joints should be at right angles to centre line of the road and at about 30 feet intervals, reinforcement is not necessary and the 2 inches thick reinforced construction has been given up because it was found impossible to keep the reinforcement in position in such thin slabs. For this reason 3 inches plain concrete has been adopted as the minimum. Surface hardening does not appear to be worth the cost.

The author feels that slabs might be extended to 50 feet in length. The joints are always a source of difficulty during construction and of weakness afterwards. The author is not aware of any failures attributable to slabs of this length The standard length of 33 feet was the length first adopted in Benares in 1926 and as it has proved satisfactory it has been standardised.

5. Various attempts have been made to make a cheap cement concrete road but no success has been obtained.

In 1927-28 in Lucknow the sandwich method was tried and 2½ inches stone was covered with a 1 : 2 mixture of cement and sand 1 inch thick

and over this $1\frac{1}{2}$ inches metal was spread. The whole was watered and rolled. The results were not satisfactory and a few years later this was used as the foundation for another concrete slab.

In 1936 rollercrete was laid in Agra. Weak mixtures of cement concrete were laid and rolled to 4 inches uniform thickness with an 8-ton roller. A 1 : 3 : 8 mixture of cement, sand and stone gave fair results for 2 years but the surface is now rough and worn into hollows and it is proposed to use it as a foundation for a normal 1 : 2 : 4 mix.

This year colloidal concrete has been tried in Lucknow. Ordinary stone metal was consolidated using water but no blinding material; one inch of 1 : 2 cement mortar was spread over the surface and tamped. The surface is wearing into holes and the experiment does not promise to be a success.

These experiments indicate that for a cement concrete road to be a success only the best materials and the best workmanship must be used —cheap methods are doomed to failure.

6. Experiments have been carried out to decide upon the best way of repairing a concrete road which is in an unsatisfactory condition.

A length of road in Lucknow in mile 1 of the Lucknow—Hardoi road which was constructed by the sandwich method in 1928 was patched and repaired with 1 : 3 : 6 cement concrete in 1929 and a $4\frac{1}{2}$ inches slab of 1 : 2 : 4 cement concrete was laid on the old foundation at a cost of Rs. 58/8/- per hundred square feet. This treatment has been very satisfactory and the road is in good condition after 10 years.

Mile 424 of the Grand Trunk Road in Benares was given a 6 inches—4 inches—6 inches slab of concrete over an insulation layer of sand in 1930 in a length of 3 furlongs. By 1937 some 41 bays had longitudinal cracks near the crown of the road and short lengths were painted with R. B. Tar. The results were not satisfactory. Another length was treated with silicate of soda which had also been used originally to harden the surface. The treatment appeared to check deterioration of the road but was not really satisfactory. The traffic was 650 tons per day on a 12-foot road.

In 1939, a 2-inch thick slab was laid over 3 old cracked slabs in mile 424 and was bonded to them. Expansion joints were made over the old joints. Half the length was reinforced with 3/16 inches round bars at 6 inches centres transversely and $1\frac{1}{2}$ feet longitudinally. The cost was Rs. 23/12/- per hundred square feet and the results are satisfactory.

A length of 100 feet in mile 424 of the Grand Trunk Road was repaired in January 1939 with a bituminous premix made with Proctor's emulsion and consolidated to one inch thickness. The cost was Rs. 12-8-0 per hundred square feet. The work is not entirely satisfactory as patching has been found necessary.

In mile 424, ruts 3 feet wide and $\frac{1}{2}$ inch to $\frac{3}{4}$ inch deep had formed in the concrete. As the traffic, is medium and the Alipore tests on the concrete are satisfactory the reason for the wearing of the surface is not known. Alipore reported that the abrasion tests of the concrete were good and the crushing load was 3 tons per square inch.

The cracking is almost certainly due to expansion in the hot weather. The insulation layer of sand doubtless prevented the concrete from being bonded to the old road surface with the result that large cracks formed instead of hair cracks. Similar, though less numerous, cracks have appeared on the Ghaziabad—Bulandshahr road and in mile 1 of Saharanpur—Ambala road where an insulation layer has been used. In these cases the effects of the cracks are not serious.

7. On the Ghaziabad—Bulandshahr road it will be remembered that 25 miles of road were constructed 12 feet wide and 5½ inch—3½ inch—5½ inch thick from 1935 to 1937.

In June 1936 one slab in mile 872 cracked with a loud explosion when the temperature was 111 degrees Fahrenheit.

In 1937 three more slabs suddenly cracked in the same way.

In 1938 five slabs cracked whilst this year eight slabs have suddenly cracked.

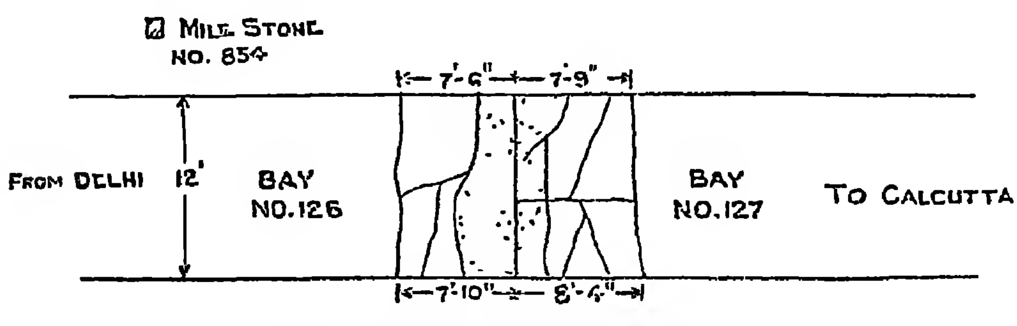
In each case the cracks have occurred when the temperatures were high and eleven cases out of seventeen have occurred in 4 miles. In some cases there has been a loud explosion like that of a gun and the slabs have been found raised at the line of fracture as much as 20 inches from the subgrade. In most cases the damage has taken place at the joint between two slabs but in at least two cases the damage has occurred in the centre of a slab. The attached diagram is a typical example of a 'burst'.

G. T. ROAD IN BULANDSHAHR DISTRICT

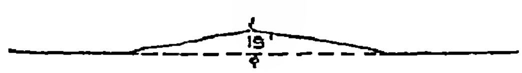
MILE 854 FURLONG 2.

Showing Details of C.C. Bay Nos. 126 & 127 Cracked
On 1-6-39 At 5 p.m.
(Temperature Roughly 109°F.)

Note.—Originally bays were constructed with ordinary cement in March 1936.



NOTE.—THE CONCRETE WAS 19" ABOVE THE SUBGRADE AT THE JOINT AFTER THE 'BURST'.



Generally a length upto 8 feet on either side of the joint is affected. The road crust forming the foundation of the concrete remains unaffected. In some cases the cracks have occurred near culverts, sometimes in villages, sometimes in low embankments, in fact anywhere at all. The author is convinced that the 'bursts' are due to expansion.

An insulation layer of sand is provided. Therefore there is no bond between the concrete and the subgrade. No expansion joints were made but the slabs were laid alternately just as in most of the other 120 concrete miles in the province. It is true that in no other cases have explosions been reported when slabs have cracked, probably because the thicker slabs were strong enough to stand the stresses whilst most of the other thin slabs have been bonded with the subgrade. There are very few cracks of any kind in the bonded slabs whilst there are numerous cracks in the insulated slabs both thick and thin.

Expansion joints are being provided wherever these bursts occur and the shattered slab is being replaced by a short new one. Expansion joints are also being provided in all new work.

An assistant engineer found one place in mile 851 of the Grand Trunk Road near Ghaziabad where the two slabs were raised at the joint 1 inch above the horizontal and, as traffic passed, dust was blown out from under the joint when the weight of the traffic forced the slabs down. The same thing was happening at the next joint. In this case fine longitudinal cracks developed in the slabs but there was no bad burst though in a neighbouring slab the concrete burst and remained 15 inches above the foundation.

In order to relieve the stresses an attempt was made to chisel out the joint between two slabs but it was impossible to make a good job of this joint.

There are numerous cracks in other slabs doubtless due to expansion but these are filled with bitumen and, though unsightly, they appear to be harmless. In August 1939 it was possible to put a knife between some adjacent slabs on this Ghaziabad road and during the cold weather there is definite separation between most slabs. It is found however that the bitumen used to protect the joints rarely penetrates more than ¼ inch into the joint. The ends of the slabs were not painted with bitumen before the alternate slabs were laid.

The author does not want to give the impression that the Ghaziabad-Bulandshahr thin concrete road is a failure. It is in fact a great success and by omitting the insulation layer and thereby bonding the concrete to the subgrade in our new roads we are now largely eliminating cracks which, after all, are disfiguring but are not of vital importance.

This question of bursts in the Ghaziabad-Bulandshahr section of road is an interesting one and it was originally suggested that perhaps rapid hardening cement was responsible. This the author thinks is disproved by the fact that 15 bursts out of 17 have occured where ordinary cement was used. An experimental slab was made with rapid hardening cement and some partially mixed cement was buried in the centre of the slab. The slab was cured in the ordinary way and after six months was thoroughly soaked to see if the partially mixed cement would cause this slab to burst. Nothing of this kind happened,

It was suggested after the first burst that it was due to local conditions—water from a drain—a potters kiln—but such theories cannot account for other bursts.

The author considers that subsequent bursts and observations of slabs lifting and dust blowing from under them as traffic passed proves conclusively that lack of space to expand under the hot sun caused the slabs to lift from the foundation and shattered them with an explosive sound just as glass or stone is shattered when suddenly broken or just as a concrete cube cracks when crushed in a testing machine.

I think the numerous cracks in other slabs are due to the same cause. They occur mostly at joints and extend 3 to 6 feet in an irregular longitudinal direction. There are few long cracks and few lateral cracks. In most cases the slabs have eased themselves by local cracking and in these 17 cases the cracks have occurred suddenly and have shattered a short length of concrete.

So far no serious damage has been done and it is hoped that as expansion joints are provided the number of bursts will decrease though it will be observed that there has been a steady increase in the number of bursts so far. About 1 mile of 6 inch—4 inch—6 inch cement concrete was laid in Saharanpur in 1937 over an insulation layer. This year a number of cracks have appeared during the hot weather doubtless due to expansion. It will be noted that more cracks appeared in the second year than in the first.

The author is unable to explain why bursts have not occurred in other 3½ inch thick slabs except by the fact that most of them have been bonded to the subgrade.

8. An interesting experiment was tried in Gonda in 1936. Two slabs of concrete 19 inches by 7 inches by 4 inches were chiselled out of the centre of a road slab 6 inch—4 inch—6 inch which was not insulated from the subgrade. It was found that where the concrete was laid on newly consolidated *kankar* the bond with the subgrade was very complete and about an inch of *kankar* came away with the slab; where the concrete had been deposited on an old *kankar* road which had been scarified and reconsolidated the bond was less complete and only small *kankar* pieces remained attached to the slab.

The slabs from Gonda were tested as beams; one with the top face uppermost and one the reverse way. If an appreciable difference in strength had been found it might have been assumed that hair cracks due to expansion or contraction existed part way through the slabs. Test showed failure of both beams under the same load and "*f*" was 470 pounds approximately. For 1 : 2 : 4 plain concrete "*f*" should be 440 pounds average and the test conclusively proved that neither slab could have been weakened by cracks due to expansion or contraction.

In Cawnpore, the thin slabs are generally laid over an old stone surface where the bond may be expected to be much better than with *kankar*. This probably accounts for the success of the thin slabs which are remarkably free from cracks in Cawnpore.

9. It will be seen that the cost of constructing a mile of 12 feet wide cement concrete road has been reduced from about Rs. 45,000/- in 1925 to about Rs. 15,000/- in 1939. This reduction is partly due to the fall in prices of materials, especially cement, but mostly it is due to the reduction in the thickness of the concrete used and due to improved methods of construction.

10. In 1939 in Cawnpore vibrated concrete was used in miles 60, 73, 74 of the Lucknow-Jhansi road. It was considered that a vibrated 1 : 3 : 6 mix would be at least as strong as 1 : 2 : 4 mix which was not vibrated and that it would be cheaper.

Three small vibrators were fitted to a heavy tamper and construction proceeded in the ordinary way. It was found that the vibrator took nearly half as long again as ordinary hand-tamping and only about 230 feet of road could be completed per day instead of about 330 feet so that the cost of laying increased considerably and the cost of the 1 : 3 : 6 vibrated mix was actually the same as an ordinary 1 : 2 : 4 mix, that is, Rs. 22/4/- per hundred square feet. In order to increase progress preliminary tamping was done by hand and the concrete was finished off with the vibrator. This appeared to be more satisfactory and increased the rate of progress to 330 feet per day. Cores are being cut from the concrete made by the different methods and the results of the tests are awaited.

The author's impression is that in India the initial cost of the vibrator and compressor (Rs. 8,000) plus running expenses coupled with the resulting slower progress due to stoppages etc., will not justify the use of vibrators for road work.

It had been decided to adopt hand-tamping followed by a vibrator using a 1 : 2 : 4 mix on a 3 inches slab of uniform thickness during the cold weather of 1939-40. The estimated cost per hundred square feet was Rs. 22/4/- This cost does not allow for depreciation of the vibrator, concrete mixer and other tools and plant nor does it allow for the Public Works Department supervision by engineers and overseers. It allows for work charged supervision and all materials used in the work.

One of the difficulties in concrete road construction is the time taken to complete a mile.

In 1938-39 in Cawnpore the actual concreting of a mile took about 20 days but before this the road surface had to be recambered and after completion the concrete had to be cured for 4 weeks. This meant that the mile was actually closed to traffic for between 2 and 3 months during which time a diversion had to be maintained.

During actual construction, 2 full time overseers were employed on the work and an assistant engineer exercised close supervision. Two concrete mixers were employed on each mile.

Altogether 7 miles of concrete were laid in Cawnpore division during the last working season.

The statement at Appendix I gives details of the cost.

In all cases the materials were supplied by contractors—the cement being supplied by the Concrete Association direct to Government. The actual construction was done by departmental labour.

In the case of the Ghaziabad—Bulandshahr road, the whole work was carried out by a contractor under the supervision of a Public Works Department assistant engineer and two overseers.

11. A comparison between the United Provinces specifications for cement concrete roads issued in 1927 and 1937 shows the following differences.

In 1927 an insulation layer was specified.

In 1937 insulation is not allowed for concrete of less than 3 inches thickness. The concrete must be bonded to the subgrade. Thicker concrete *may* be bonded. In the light of further experience the author would now advocate the bonding of the concrete to the road whatever the thickness. The author considers that the insulation layer of sand should be entirely omitted.

In 1927 thickened edges were specified.

In 1937 this is optional and a uniform thickness of concrete in now usual.

In 1927 slabs were laid about 33 feet long with plain butt joints at 60 degrees to longitudinal axis of the road in alternate bays. No expansion joints or longitudinal joints were provided and adjacent ends of slabs were not painted with bitumen.

In 1937 slabs were specified as 33 feet long with plain butt joints at right angles to the longitudinal axis in either alternate or continuous bays. With alternate bays the ends of the completed slabs are painted with hard grade bitumen before laying intermediate bays. Expansion joints at least 3/8 inch thick every 100 feet have since been specified. Longitudinal joints are given in roads exceeding 16 feet in width.

In 1927 hydrated lime was mixed with cement in the proportion of 1 to 20 but this is now omitted as there is no apparent advantage in using the lime. Similarly the treatment of the surface with silicate of soda is now omitted.

A copy of the 1937 specification is attached as Appendix II.

The concrete miles already constructed in the United Provinces are very satisfactory on the whole. Most of them are narrow and during the rains the edges of the concrete become exposed so that it is difficult and sometimes dangerous for motors to swing off and on to the concrete in order to pass other vehicles. This difficulty applies equally to narrow bituminised roads where the edges are protected by brick on edge. In all these cases gangs have to be employed continuously on filling in the edges of the road. The best remedy lies in making the roads wider than 12 feet so that 2 lines of traffic can pass on the actual metalled surface.

Another alternative, and perhaps the only possible solution for India, is to protect the edges by some material like *kankar* or brick ballast. The author considers that the concrete, which would take 90 per cent. of the traffic, might be made 9 feet wide and its edges might be protected by *kankar* or brick or stone consolidated in strips 1½ feet wide on either side giving the

same total road-width as at present but avoiding the dangerous drop from the concrete on to the *pattries*. The *kankar* would merge gradually into the earthen edges of the road.

A saving of 20 per cent. on a 12 feet wide road might be made in this way and the cost of a mile of 12 feet wide equivalent concrete road might be reduced from Rs. 15,000/- to Rs. 12,000/-.

In conclusion the author would say that before the outbreak of war in 1939 a plain cement concrete road 12 feet wide and of 3 inches uniform thickness could be constructed in the United Provinces for Rs. 15,000/- and would be expected to last for at least 20 years under 1000 tons of traffic per day. Maintenance of the concrete would be negligible. If the traffic was between 1000 and 2000 tons per day the concrete should be 4 inches thick and would cost Rs. 20,000/- per mile whilst for heavier traffic it would be advisable to use cement concrete 6 inches thick.

APPENDIX I.

MILE 73 LUCKNOW-JHANSI ROAD

1938-39.

3"—3"—3" slab 12 feet wide 1 : 3 : 6 proportion concrete vibrated cum hand-tamped. Area 1716 square yards.

Serial No.	Items	Quantity	Rate	Cost	Rate per square yard Rs. as. p.
1.	Cement ordinary Rapid Hardening	27.525 2.600	35 6 5 43 6 5	1078 0 0	..
2.	1 inch—1½ inch Tamaliya metal	2733	25 1 7	686 0 0	..
3.	½ inch—1 inch Tamaliya metal	1480	33 6 10	491 6 0	..
4.	Kalpi coarse sand ..	2362	15 14 5	375 11 0	..
				2634 1 0	1 8 7
5.	Subgrading ..	..	..	..	0 0 1.5
6.	Laying concrete ..	..	..	..	0 ~~2~~ 3 0.3
7.	Forms ..	..	..	..	0 0 5.0
8.	Curing ..	..	..	..	0 0 8.7
9.	Diversion ..	..	..	..	0 0 4.4
10.	Making patries ..	..	..	..	0 0 3.3
11.	Tools and plant ..	..	..	..	0 0 5.3
12	Establishment ..	..	..	..	0 0 4.0
13.	Hardening ..	..	..	..	0 0 0
14.	Contingencies Water Supply etc.	..	..	..	0 0 0.4
	Total ..	..	..	..	1 14 3.9 say, 1,14,4 per square yard *say, 21/- per hundred square feet.*

APPENDIX I.—(*Continued.*)

MILE 73 LUCKNOW—JHANSI-ROAD.

1938-39.

3"—3"—3" slab 12 feet wide 1 : 2 : 4 proportion concrete hand-tamped only. Area 2888 square yards.

Serial No.	Items	Quantity	Rate	Cost	Rate per square yard Rs. as. p.
1.	Cement ordinary, rapid hardening	61.575 3.975	35 6 5 43 6 5	2350 14 4	..
2.	1 inch—1½ inch Tamaliya metal	4024	25 1 7	1010 3 9	..
3.	½ inch—1 inch Tamaliya metal	2176	33 6 10	728 10 6	..
4.	Kalpi coarse sand ..	3486	15 14 5	555 5 9	..
				4645 2 4	1 9 8
5.	Subgrading ..	..	..	..	0 0 1.5
6.	Laying concrete ..	..	..	..	0 2 1
7.	Forms ..	..	..	..	0 0 6.0
8.	Curing ..	..	..	..	0 0 8.7
9.	Diversion ..	..	..	..	0 0 4.4
10.	Making patries ..	..	..	..	0 0 3.3
11.	Tools and plant ..	..	..	..	0 0 5.3
12.	Establishment ..	..	..	..	0 0 4.0
13.	Hardening ..	..	..	..	0 0 0
14.	Contingencies Water supply etc.	..	..	..	0 0 0.4
	Total ..	..	..	..	1 14 6.6 per square yard *say, 21/4/- per hundred square feet.*

APPENDIX II

Specification for cement concrete roads

Revised 1937

I—GENERAL

A cement concrete road consists of a cement concrete slab of a specified mixture of suitable materials laid on a suitable sub-grade. Slabs less than 3 inches thick are classified as thin slabs and those 3 inches or more in thickness as thick slabs

II—SUB-GRADE

By the sub-grade is meant all construction between country level and the base of the slab

The top of the sub-grade shall not be less than 12 inches above anticipated water level in the side drains or on the surrounding country which shall be so drained that no storm water will stand against the sub-grade for a longer period than 12 hours.

If the upper portion of the sub-grade is an existing metalled road and if the thickness of the metal is 6 inches or more the surface may be left undisturbed if its shape approaches that required for the underside of the concrete slab. Otherwise the surface shall be scarified to a depth of 2 inches, additional metal added if necessary and the whole reconsolidated after shaping to the profile of the underside of the concrete slab.

If the existing metalled crust is less than 6 inches thick a complete new coat, or coats, of metal shall be given of such thickness that the final thickness of the metalled crust is not less than 6 inches.

Though not essential, it is preferable that the width of the water-bound metal on the sub-grade should be six to nine inches wider than the width of the slab proposed.

If the concrete slab is to be wider than the existing metalled surface the latter shall first be widened with stone or kunker (as decided by the Deputy Chief Engineer) and consolidated to a final thickness of not less than six inches. Thereafter the whole width of the road shall be given a complete coat of new metal consolidated to the shape required.

When it is proposed to lay a concrete road on a newly constructed sub-grade, the embankment shall be made up in accordance with Public Works Department Specifications. The embankment shall stand one complete rains and shall then be finished off with a coat of stone ballast or kunker (as decided by the Deputy Chief Engineer) consolidated to the required shape and not less than six inches thick when consolidated. The finished surface of the sub-grade shall be firm and uniform.

III—PREPARATION OF SUB-GRADE.

All thin slabs shall be anchored to the sub-grade; the surface of the latter shall be brushed so as to remove all fine and loose particles of stone, kunker or moorum and the concrete deposited on the surface which has thus been cleaned. If the upper portion of the sub-grade is of water-bound stone, and if the Deputy Chief Engineer so directs, the surface shall be given a wash of cement and water just prior to depositing the concrete.

In the case of thick slabs no steps will normally be taken to bond them to the sub-grade. If the surface of the sub-grade is rough or uneven, sand shall be spread so as to fill up the hollow places and to bring the shape

to that required for the underside of the slab. The amount of sand used shall be the minimum necessary for the purpose. Since it is intended that the sand shall be used merely as a "filler" to avoid the use of an excessive quantity of concrete, the sand is not intended to act as an insulation layer between the sub-grade and the slab. If so directed by the Deputy Chief Engineer, thick slabs may be bonded to the sub-grade in the manner described for thin slabs.

IV—MATERIALS

All cement shall be obtained through the Cement Marketing Co. and shall comply with British Standard Specifications for slow setting portland cement, *vide* Annex "A". Rapid hardening cement when used shall in addition have a tensile strength of 650 lb. per square inch at the age of seven days when mixed with three parts of standard sand. A certificate of test shall be obtained from the manufacturers for each brand of cement ordered but samples of all consignments shall pass the field tests mentioned in Annex "B". Cement.

Cement shall be ordered in quantities which can be utilized within one month and shall be stored in a dry place close to the work. All cement stored longer than a month shall be tested for deterioration and no cement which falls short of specification shall be used on the work.

All water used for mixing shall be clean and free from oil, acids, alkalis and vegetable matter. Water.

The fine aggregate shall consist of sand or stone screenings and shall be clean, hard, sharp and durable. An ideal sand would comply with the sieve analysis given below but a sand may be accepted which complies with the analysis in all but one sieve size: sand which fails to satisfy the analysis in more than one sieve size shall only be used with the prior approval of the Deputy Chief Engineer. Fine aggregate

Sieve analysis of ideal sand

Sieve size meshes per lineal inch	8	16	30	50	100	Fineness modulus
Percentage retained on each sieve.	0 to 15	15 to 45	40 to 70	70 to 90	95 to 100	2.2 to 3 2

If necessary two sands may be mixed in certain proportions to obtain a combined sand which will conform to the specifications.

All fine aggregate shall pass the field and laboratory tests detailed in Annex "B".

River sand need not be washed but pit sand shall always be washed.

This will consist of crushed stone passed as suitable by the Government Test House, Alipur. It shall be clean, hard, durable, and free from thin elongated or laminated pieces. Coarse aggregate.

Limestone shall not be used for top coat concrete.

The whole of the coarse aggregate shall pass through a screen having square meshes whose linear dimensions are not greater than one half the least thickness of the slab. Any part of the coarse aggregate which passes a ¼-inch mesh sieve shall be regarded as fine aggregate. If the coarse aggregate is not what is termed the "run of the crusher", or alternatively hand broken and unscreened stone, it shall consist of various grades so proportioned as to give the least void content in the mixture. The void content should not exceed 42 per cent.

Aggregate containing deleterious matter shall be washed before use.

Reinforcement. If any reinforcement is to be used, the steel for the purpose shall comply with Public Works Department Specifications

V—FORMS

These shall normally be of steel channels the depth of which is equal to the depth of the outer edges of the slab. The length of steel forms shall preferably be equal to the length of the slabs to be laid but shall in no case be less than 20 feet. Steel side forms shall be rigidly bedded on the outer three inches of the sub-grade and pegged to the sub-grade at intervals of not more than three feet. If the concrete is being laid to the full width of the existing water-bound crust (see section II) the side forms shall be firmly bedded on the existing sides of the road but must be supported underneath by a carefully laid layer of bricks or by a continuous line of wooden blocks specially made for the purpose. The forms shall be turned over top to bottom every two or three times that they are used. The greatest care shall be taken to ensure that side forms are laid absolutely true to level (or gradient) and that the forms on each side of the road are at equal levels (except where super-elevation is to be given).

Side forms shall be oiled or greased before the concrete is laid and shall not be removed until 24 hours after the concrete has been laid.

For curves side forms of brick-in-clay cement-plastered shall be used unless curved steel forms are available.

VI—THE MIX

Unless otherwise ordered by the Engineer-in-charge the mix for the concrete shall be as follows:

1 bag of portland cement.
2 1 c ft. of fine aggregate.
4.8 c. ft. of coarse aggregate.
5 to 6 gallons of water according to temperature and weather.

If the use of rapid hardening cement has been agreed to by the Deputy Chief Engineer the mix shall be as below:

1 bag of rapid hardening cement
2 8 c. ft. of fine aggregate.
5 6 c ft. of coarse aggregate.
5 8 to 7.0 gallons of water according to temperature and weather.

More than the above quantities of water shall not be used without the specific sanction of the Deputy Chief Engineer.

VII—MIXING

Hand mixing. Hand mixing shall be resorted to only in emergency and it is preferable to postpone the work until a mechanical mixer is available.

Specified quantity of sand shall first be placed in the mixing tray. Size about 8' × 4' × 9" and over it the specified quantity of cement shall be spread. All the dry sand and cement shall be turned over with the shovels at least three times until the mixture is of a uniform colour. The specified quantity of coarse aggregate shall now be added, and the whole mixture turned over again at least three times. The specified quantity of water shall next be added slowly through a hose attached to a watering can while the process of turning the mixture over is being carried out. The mixing shall be continued until the whole batch has reached an even consistency and the mortar is spread evenly through the batch.

Machine mixing. If machine mixing is adopted batch mixers shall be used and shall be of such size that only whole bags of cement need be used for the batch.

Dry materials shall first be mixed for a minute. The specified quantity of water shall then be added and all mixed again for not less than a minute and a half. The mixer shall rotate at a speed of 15 to 20 revolutions per minute.

Concrete shall be mixed only in quantities that can be laid and finished before the cement sets.

To test the consistency of the mixed concrete, slump tests shall be made as described in Annex "B". Slump test

Mortar or concrete which has partially set shall not be retempered by being mixed with additional material or water. Retempering.

VIII—CONSTRUCTION

The slab shall be constructed by—

(1) the alternate bay or

(2) the continuous slab method.

Alternate bays shall first be laid to the cross sectional dimensions shown on the plan and when ordinary cement is used the intermediate bays shall not be laid till all concrete in the first set of bays is five days old. When rapid hardening cement is used the alternate bays may be laid after two days but it is preferable to allow five days. Alternate bay method

Joints shall be formed by painting the ends of the first set of bays with hard grade bitumen before laying intermediate bays.

Transverse joints shall be plain but joints at right angles to the direction of traffic. Their spacing shall be 33 feet for all thicknesses except for experimental purposes with Deputy Chief Engineer's approval.

In this method bays shall be laid continuously. Construction joints shall be formed as follows: a dividing strip of 3/16 inches steel shall be cut to a shape corresponding to the cross section of the slab, and, if the width of the road exceeds 10 feet shall then be cut into two equal halves the length of each being equal to one-half the width of the slab. If the slab width is ten feet or less the dividing strip shall be used in one piece its length being equal to the width of the slab. At the outer end of each half when the dividing strip is in two portions, or at one end when the strip is used as a single unit, there shall be left a projection in which a hole is drilled to take an iron rod for lifting. When the concrete approaches the position of the construction joints the dividing strip, or strips, are placed on the sub-grade and supported on the further side (away from the bay being constructed) by a wooden bulkhead in sections. The number of sections into which the bulkhead is divided will depend on the width of the slab but shall never be less than three and the length of the sections shall not be more than three feet. If preferred, the steel dividing strip may be greased with a soft grade of motor grease and covered with grease proof paper folded *under* the steel strip and of such a width that the upper edges of the paper are slightly below the top of the strip. Continuous bay method.

When the concrete on one side of the strip has been laid, alternate sections of the bulkhead are removed and concrete rapidly deposited in the gaps thus made; the remaining sections are then removed and concrete deposited and rammed.

Thirty to forty-five minutes after laying the concrete at the joint, the strip (or strips) shall be removed by lifting the outer end by the aid of an iron rod slipped through the hole. Where the dividing strip is in two halves one shall be removed at a time. The outer end is lifted until about half the strip is exposed and the strip is then removed by drawing it in the direction of its own length, care being taken to prevent the further end, as it leaves the concrete, from damaging the surface,

When the strip or strips have been removed any slight abrasions of the edge of the joint shall be repaired with a trowel and the edges then slightly rounded with a special float.

Longitudinal joints.

When the width of the road to be constructed exceeds 16 feet, it shall be laid with a longitudinal joint or joints so that the width of each strip does not exceed 16 feet. The joint shall be formed in the same manner as in the alternate bay method of construction.

Curve and super-elevation.

The radius of curves in the plains shall, if possible, be made 1,000 feet or more and shall not be less than 200 feet. In the hills the radius shall be made as large as practicable. Super-elevation in inches per foot width of road:

320/R in the plains,
80/R in the hills,

where R is the radius of curvature in feet

The slab shall be widened on curves as follows:

(a) In the plains where there are pattries no widening shall be done.

(b) In the hills a 12-foot wide slab shall be widened 5 feet.

(c) In the hills at hair-pin bends the largest available width shall be concreted subject to the maximum of 30 feet.

IX—PLACING CONCRETE

Watering.

Before placing the concrete the sub-grade shall be sprinkled with as much water as it will readily absorb but there shall be no pools of water standing on it. It is preferable to have the sub-grade sprinkled or thoroughly wet from 12 to 36 hours in advance of placing concrete, where such procedure seems necessary.

Laying.

Concrete shall be laid in two layers if the thickness of the slab is to be more than four inches and in one layer if it is to be four inches or less. The lower layer shall not advance more than 1½ inches in front of the upper layer and more than 20 minutes shall not elapse before the lower layer is covered with the upper.

The upper layer shall be laid ¼ inch to ½ inch higher than the profile to permit of its being rammed into position with the tamper.

Concrete shall be laid over the entire width of the slab and between joints in one continuous operation. While being laid it shall be sliced and spaded with suitable tools and shall then be brought to correct camber by means of heavy screed or tamper of solid wood about 13 inches deep and not less than three inches wide. The bottom of the tamper shall be shod with sheet iron. During tamping the surface shall be carefully inspected for high and low spots and any correction necessary made by adding or removing concrete

Longitudinal floating.

After tamping the entire surface shall be floated longitudinally with a wooden board not less than 16 feet in length and eight inches wide with handles at each end. The float shall be operated by a man at each end standing on a suitable bridge spanning the road. The float is drawn backwards and forwards with strokes of about two feet and advancing slowly from one side of the slab to the other. When the bridges are moved forward they should be so placed that the next floating overlaps the first by about three feet

Rolling

As an alternative to longitudinal floating the surface may be rolled transversely with a roller about five feet long and 8 inches to 12 inches in diameter made of sheet steel or, preferably, concrete piping. The roller shall have two handles fixed to a central axle and shall be worked backwards and forwards across the slab and gradually advancing at the same time.

The concrete shall be finished by using a strong canvas belt not less than 6 inches or more than 12 inches wide and at least two feet longer than the width of the pavement. The belt is to be applied with a combined crosswise and longitudinal motion the strokes being not more than about 12 inches long but these should be reduced to short strokes of about 4 inches as soon as the water sheen has disappeared from the surface of the concrete. Belting.

Edges of the slab at the sides shall be chamfered at 45 degrees for a width of two inches with a suitable edging tool. Chamfering.

The finished surface, when tested with a straight edge 10 feet long placed longitudinally on the road should not show deviations more than ¼ inch from a straight line. Finished surface.

X—CURING

There shall be kept at the site of work a number of strips of hessian or burlap sufficient to cover at least two bays of the road. These strips shall have bamboo, or light wood, strips sewn at each end and as soon as the belting and edge finishing are completed one of these strips previously damped, shall be placed on the surface of the concrete. As the work proceeds more strips shall be brought forward and similarly placed so that the moment work on any portion is finished the concrete is protected from drying. These strips shall be kept moist by light spraying as necessary. Protection

When the concrete is about two hours old the strips may be replaced, by damp cement bags.

On the day following laying the bags shall be removed and the whole surface of the concrete covered with earth to a depth of six inches. The earth shall be thoroughly wetted as soon as it is placed and will then be divided into ponds about 5 feet square which shall be kept saturated with water in the case of ordinary cement until the 21st day after laying. If the concrete is not to be silicated the earth covering shall be allowed to dry out until the 28th day after which it may be removed and the road opened to traffic. Wet earth cover

If rapid hardening cement has been used the earth may be allowed to dry out from the 10th day after laying and the road opened to traffic on the 14th day.

If the use of silicate of soda had been ordered by the Deputy Chief Engineer the treatment shall be applied on about the 25th day after laying, in the case of ordinary cement, and about the 12th day in the case of rapid hardening cement. Silicating.

The surface of the concrete shall be thoroughly cleaned with stiff brooms and water and three applications of silicate solution given at 24 hours' intervals. The solution shall consist of commercial silicate of soda (P. 84 grade) and four parts of water and one gallon of the solution should cover 200 square yards.

XI—FILLING JOINTS

Immediately prior to opening the road to traffic the joints must be filled and protected. If it is possible to insert a thin knife in the joints they should first be cleaned in that way and then filled with bitumen which should overlap the edges of the slabs by about two inches on each side. The bitumen should be of a fairly hard grade so as to avoid undue softening in the hot weather but it must also be of a fairly thin consistency if it is to penetrate fully into the joints; a cut-back seems likely to prove suitable.

During the early months of its life the road must be frequently inspected and, where necessary, more filler added if that already applied appears to have sunk further into the joints.

XII—STRENGTH OF CONCRETE AND TESTS

Tests

The tests detailed in the annexes attached shall be carried out from time to time during the construction of the work as directed by the Engineer-in-charge.

When so directed by the Deputy Chief Engineer test cubes shall be made during the progress of the work and submitted to Alipur Test House *for testing.*

Strength

The compressive strength of the concrete when tested by 6 inch cubes or cylinders shall not be less than that given in the following table:

—	With ordinary cement	With rapid hardening cement
	lb.	lb.
After 7 days	2,250	2,750
After 14 days	2,750	3,500
After 21 days	3,000	3,750
After 28 days	3,500	4,250

Note —

Circular No $\frac{12\ P\ W}{113\ W/1938}$ dated Lucknow June 20th 1938 lays down:

"Expansion joints shall invariably be left in all concrete road works and shall be spaced not more than 100 feet apart and made not less than ¾ inch thick".

ANNEX A

Extract from the British Standard Specification

Portland cement samples for testing and by whom to be taken

2. A sample or samples for testing may be taken by the purchaser or his representative, or by any person appointed to superintend the works for the purpose of which the cement is required or his representative, or by any expert analyst employed or instructed by such purchaser or person, or the representative of such purchaser or person.

Samples for testing and how to be taken

3. Each sample for testing shall consist of approximately equal portions selected from twelve different positions in the heap or heaps when the cement is loose, or from twelve different bags, barrels or other packages when the cement is not loose, or where there is a less number than twelve different bags, barrels or other packages, then from each bag, barrel, or other package. Every care shall be taken in the selection, so that a fair average sample may be taken.

Facilities for sampling and identifying

5. The vendor shall afford every facility, and provide all labour and materials for taking and packing the sample for testing the cement and for subsequently identifying the cement sampled.

Tests

7. The sample for testing shall be tested in the manner hereinafter mentioned for—

(*a*) Fineness.
(*b*) Chemical composition.
(*c*) Tensile strength (neat cement).
(*d*) Ditto (cement and sand).
(*e*) Setting time.
(*f*) Soundness.

And before any sample is submitted to tests (*c*), (*d*) and (*f*), it shall be spread out for a depth of 3 inches for fourteen hours in a temperature of from 58 to 64 degrees Fahrenheit.

Test for fineness

8. The cement shall comply with the following conditions for fineness: One hundred grammes (or say 4 oz.) of cement shall be continuously sifted for a period of 15 minutes on each of the undermentioned sieves and in the order of succession given below with the following results:

(1) The residue on a sieve 180 × 180 = 32,400 meshes per square inch shall not exceed 10 per cent.

(2) The residue on a sieve 76 × 76 = 5,776 meshes per square inch shall not exceed 1 per cent.

Air-set lumps in the samples may be broken down with the fingers, but nothing shall be rubbed on the sieve.

The sieves shall be prepared from wire-cloth, and the diameter of the wire for the 32,400 mesh shall be .0018 inch, and for the 5,776 mesh, .0044 inch. The wire-cloth shall be woven (not twilled), the cloth being carefully mounted on the frames without distortion.

Test for chemical composition

9. The cement shall comply with the following conditions as to its chemical composition. The proportion of lime, after deduction of the proportion necessary to

combine with the sulphuric anhydride present, to silica and alumina when calculated (in chemical equivalents) by the formula $\frac{Ca\,O}{Si\,O_2 \times Al_2O}$ shall be not greater than 2.9 nor less than 2.0. The percentage of insoluable residue shall not exceed 1.5 per cent.; that of magnesia shall not exceed 4 per cent. and the total sulphur content calculated as sulphuric anhydride (SO^3) shall notexceed 2.75 per cent. The total loss on ignition shall not exceed 3 per cent.

Test for tensile strength (neat cement)

10. The breaking strength of neat cement shall be ascertained from briquettes of the shape shown in fig. 1, plate 1. The briquettes shall be prepared in the following manner:

Preparation of briquettes—The cement shall be mixed with such a proportion of water that the mixture shall be plastic when filled into the moulds used for forming the briquettes.

The cement, gauged as above, shall be filled into moulds of the form required to produce briquettes for the shape shown in fig. 1, plate 1, each mould resting upon a non-porous plate. In filling the moulds the operator's hand and the blade of the ordinary gauging trowel shall alone be used. The trowel shall weigh about 7½ oz. No ramming or hammering in any form will be permitted, nor shall any other instrument or apparatus other than the trowel before described be employed for this operation. The moulds after being filled may be taken to the extent necessary for expelling the air.

Clean appliances shall be used for gauging, and the temperature of the water and that of the test room at the time the above operations are being performed shall be from 58 to 64 degrees Fahrenheit.

The briquettes shall be kept in a damp atmosphere for 24 hours after gauging when they shall be removed from the moulds and immediately submerged in clean fresh water and left there until taken out for breaking. After they have been so taken out and until they are broken, the briquettes shall not be allowed to become dry.

Breaking.—The briquettes shall be tested for breaking strength at seven days after gauging, six briquettes for period. The breaking strength shall be the average tensile breaking strength of the six briquettes for the period. The briquettes to be tested shall be held in strong metal jaws of the shape shown in figs. 2 and 3, plate 1, and the load shall be steadily and uniformly applied, starting from zero, and increased at the rate of 100 lb. per square inch of section in 12 seconds.

The breaking strength of the briquettes at seven days after gauging shall be not less than 600 lb. per square inch of section.

Test for tensile strength (cement and sand)

11. The breaking strength of cement and sand shall be ascertained from briquettes also of the shape shown in fig. 1, plate 1. The briquettes shall be prepared in the following manner:

Preparation of briquettes—A mixture of cement and sand in the proportion of one part by weight of cement to three parts by weight of the standard sand specified below shall be gauged with sufficient water to wet the whole mass throughout without any excess of water being present.

The mixture gauged as above shall be evenly distributed in moulds of the form required to produce briquettes of the shape shown in fig. 1, plate 1, each mould resting upon a non-porous plate. After filling a mould a small heap of the mixture shall be placed upon that in the mould and patted down with the Standard Spatula shown in fig. 4, plate 1 until the mixture is level with the top of the mould. This last operation shall be repeated a second time and the mixture patted down until water appears on the surface; the flat only of the Standard Spatula is to be used, and no other instrument or apparatus is to be employed for this operation. The mould after being filled may be shaken to the extent necessary for expelling the air. No ramming or hammering in any form will be permitted during the preparation of the briquettes, which shall then be finished off in the moulds by smoothing the surface with the blade of a trowel.

Clean appliances shall be employed for gauging, and the temperature of the water and that of the test room at the time the above operations are performed shall be from 58 to 64 degrees Fahrenheit.

The briquettes shall be kept in a damp atmosphere for 24 hours after gauging, when they shall be removed from the moulds and immediately submerged in clean fresh water, and left there until taken out for breaking. The water in which they are submerged shall be renewed every seven days, and maintained at a temperature of between 58 and 64 degrees Fahrenheit. After they have been so taken out and until they are broken, the briquettes shall not be allowed to become dry.

Breaking—The briquettes shall be tested for breaking strength at 7 and 28 days respectively after gauging, six briquettes for each period. The breaking strength shall be the average tensile breaking strength of the six briquettes for each period. The briquettes to be tested shall be held in strong metal jaws of the shape shown in figs. 2 and 3, plate 1, and the load steadily and uniformly applied starting from zero, and increased at the rate of 100 lb. per square inch of section in 12 seconds.

The breaking strength of the briquettes at seven days after gauging shall be not less than 325 lb. per square inch of section.

The breaking strength of the briquettes at 28 days after gauging shall show an increase of the breaking strength at seven days and shall be not less than the number of pounds per square inch of section arrived at from the following formula:

$$\text{Breaking strength at seven days plus } \frac{10{,}000}{\text{breaking strength at 7 days}}$$

Standard sand—The standard sand shall be thoroughly washed and dried and shall pass through a sieve of 20 x 30 meshes per square inch, and be retained on a sieve of 30 x 30 meshes per square inch. The sieve shall be prepared from wire-cloth, the wires being .0164 inch and .0108 inch in diameter respectively. The wire-cloth, shall be woven (not twilled), the cloth being carefully mounted on the frames without distortion.

Test for setting time

12. Unless a specially quick-setting cement is specified or required, it shall have an initial setting time of not less than 30 minutes and a final setting time of not more than 10 hours.

If a specially quick-setting cement is specified or required, it shall have an initial setting time of not less than two minutes, and a final setting time of not more than 30 minutes.

Vicat Needle Apparatus—The initial and final setting times of the cement shall be determined by means of the Vicat Needle Apparatus shown on plate 2.

For the purpose of carrying out the tests a test block shall be made as follows:

Neat cement shall be gauged in the manner and under the conditions referred to in clause 10, and the gauging shall be completed before signs of setting occur. The test block shall then be made by filling the cement gauged as above into the Vicat mould shown at E, plate 2, the mould resting upon a non-porous plate. The mould shall be completely filled, and the surface of the test block shall then be smoothed off level with the top of the mould.

Determination of initial setting time—For the determination of the initial setting time the test block confined in the mould and resting on the plate shall be placed under the rod bearing the needle; the latter shall then be lowered gently into contact with the surface of the test block and quickly released, and allowed to sink into the same. This process shall be repeated until the needle, when brought into contact with the test block and released as above described, does not pierce it completely. The period elapsing between the time when the cement is filled into the mould and the time at which the needle ceases to pierce the test block completely shall be the initial setting time above referred to.

Determination of final setting time—For the determination of the final setting time the needle (C) of the Vicat apparatus shall be replaced by the needle

(F) shown separately on plate 2. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression thereon, while the attachment shown in a figure on plate 2 fails to do so. In the event of a scum forming on the surface of the test block, the underside of the test block may be used for determining the final set.

Test for soundness

13. The cement shall be tested for soundness by the "Le Chatelier" method. The apparatus for conducting the "Le Chatelier" test is shown on plate 2. The moulds shall be kept in good condition, having the jaws not more than 0.5 mm. apart.

In conducting the test the mould shall be placed upon a small piece of glass and filled with cement gauged in the manner and under the conditions referred to in clause 10, care being taken to keep the edges of the mould gently together whilst this operation is being performed. The mould shall then be covered with another glass plate, upon which a small weight shall be placed, and the whole shall then be immediately submerged in water at a temperature of 58 to 64 degrees Fahrenheit, and left there for 24 hours.

The distance separating the indicator points shall then be measured, and the mould again submerged in water at 58 to 64 degrees Fahrenheit, which shall be brought to boiling point in 25 to 30 minutes and kept boiling for six hours. The mould shall then be removed from the water and allowed to cool and the distance between the points again measured, the difference between the two measurements represents the expansion of the cement. When the sample has been aerated for 24 hours in the manner described in clause 7, the expansion as above determined shall not exceed two millimeters. In the event of the cement failing to comply with this test, a further test shall be made from another portion of the same sample after it shall have been aerated for a total period of seven days in the manner before described when the expansion determined as above shall not exceed five mm.

Non-compliance with tests

14. Any cement which does not comply with the whole of the tests and analysis hereinbefore specified, or which has not been stored in the manner provided in clause 4, may be rejected as not complying with the Specification.

Copies of vendor's tests and analysis, etc.

15. The vendor shall, if required, furnish free of cost a copy of any document in his possession showing the result of any test or analysis made for him or for any other person of any cement sold or offered for sale to the purchaser or of the lot from which the cement so sold or offered for sale has been or is to be taken, and shall, if required at the time of purchase, furnish, free of cost, a certificate that the cement so sold or offered for sale has been tested and analysed, and that such tests and analysis comply in all respects with this Specification, but the furnishing of such copies of documents or the giving of such certificate shall not preclude the purchaser from rejecting any cement which does not comply with this Specification.

Delivery

16. Cement shall be delivered in bags, barrels or other packages bearing the Manufacturer's name. A purchaser desiring to have the cement delivered in bags, barrels or packages sealed or of any particular size must so specify at the time of ordering.

ANNEX B

(FIELD TESTS RELATING TO THE SPECIFICATIONS)

I—Laboratory test for sand

1. *Decantation test for silt, etc.*—This test covers the quantity of silt, loam, clay, etc., in sand or fine aggregate. Fill a 16-ounce graduated bottle with a wide mouth with a fair sample of the sand to be tested to the 7-ounce mark, add clean water to make up to 14 ounces, then shake the contents of the bottle vigorously for one minute. If more than a $\frac{1}{8}$ ounce of fine sediment appears above the sand after it has been allowed to settle for one hour, the sand is unsatisfactory for concrete or mortar unless it is washed to remove the silt, etc Sand or aggregate having a coating of material such as bitumen, etc., which cannot be removed by washing must not be used for concrete work, as such coatings will prevent the aggregate from binding properly with the cement.

2. *Organic impurities in sand*—This test is to discover the presence of injurious organic compounds in natural sands that have been deposited by leaves, etc. The principal value of the test is in furnishing a warning that further tests of the sand are necessary before they are used in concrete. If the sand to be tested produced any colour in the sodium hydroxide solution used, then the sand should be subjected to strength tests in mortar or concrete cubes before being used for practical concrete work.

A fair sample of the sand must be taken about two lb. in weight. Fill a 16-ounce graduated bottle with a wide mouth upto the 6-ounce mark with the sand to be tested. Then add a 3 per cent. solution of sodium hydroxide in water until the volume of sand and liquid, after shaking, gives to a total volume of 16-ounces The solution is made by dissolving one ounce of caustic soda (in sticks) in a quart of boiled and cooled water, or any chemist will prepare the solution ready for use. Let it settle for 24 hours. The presence of organic matter is indicated by the colour of the liquid above the sand. If the liquid is water-white or not darker than a faint straw tint, it signifies that there is little or no organic matter in the sand. If the liquid is darker than a light straw colour, the sand contains injurious amounts of impurities and should be rejected for use, or only used after being washed and when a re-test shows it to be suitable for concrete and mortar.

In any case where the test shows a dark tint, the sand should be tested by making concrete cubes from it, because a dark tint indicates the presence of deleterious organic matter of which an appreciable amount reduces the weathering qualities of the concrete.

II—Slump test for consistency of concrete

This test is used to measure and control the consistency of the concrete of any type of work, and to secure its full benefits it must be used several times a day in wet weather when making concrete.

The test specimen should be formed in a mould of no. 16 gauge galvanized metal in the form of cone 12 inches high. 8 inches diameter of base, and 4 inches diameter of top, open at both ends and provided with handles that can be used as foot-holders when necessary, as shown in the sketch.

The mould is filled with concrete at the mixer immediately after the whole of the concrete has been discharged. When testing concrete that has been hauled from a central mixing plant, the sample must be taken after it has been dumped on to the place depositing, or other place.

The cone mould must be placed on a non-absorbent surface, such as a slab of slate, or of metal, and the operator must hold the mould firmly in place while it is being filled.

The mould must be filled about *quarter full* with the concrete which must be puddled, using 20 to 30 strokes of $\frac{1}{2}$-inch round metal rod with a pointed end. The filling must be completed in successive layers similar to the first and the top struck off so that the mould is exactly filled.

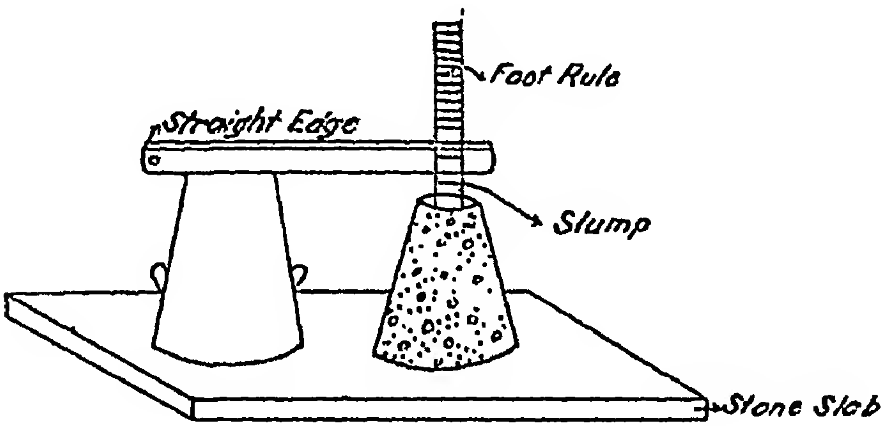
The mould must be removed by being raised vertically, exactly three minutes after being filled, and the concrete allowed to subside until quiescent. Then the drop of the concrete is measured.

The consistency shall be recorded in terms of inches of subsidence of the concrete during test, and is known as the Slump. Slump: 12 inches of height after subsidence.

The slump test requirement is intended to ensure concrete mixed with the minimum of water necessary to produce a plastic mixture of unvarying quality.

For road concrete work, with average aggregates and proportions, a slump of 3/4 inch has been found suitable. A slump of more than 1 inch shall not be permitted.

The test is not applicable when there is a considerable quantity of coarse aggregate over two inches in size in the concrete unless the cone mould is made 50 per cent. larger than the standard cone mould, viz., 12 inches diameter at the bottom, 6 inches at the top, and 18 inches high. The slump figures will also be increased 50 per cent. for the subsidence.



III—Field test for cement

Where cement has been stored for a period in excess of the month the Engineer shall ascertain whether there has been any deterioration, by making the following field test before issuing the cement.

Take a pound of cement and mix into a stiff paste with a trowel and mould on a piece of glass a pat three inches square and one inch thick. Use the minimum amount of water. In 18 to 24 hours the pat should have hardened sufficiently to resist any impression by the thumb-nail. In 48 hours it should not be easy to break the pat in the fingers. The pat should be preserved during the test under cover in a moderately warm room or shed.

IV—Field test for sand

Field test as to the quality of the sand shall be made as follows.

Having tested the cement and found it sound, mix 1 lb. of cement with 2 lb. sand. The minimum amount of water to produce a stiff paste should be added and a cubical block moulded on a piece of glass. This block should be kept under the same conditions as described for the cement pat in paragraph 5. If after 24 hours or 48 hours the block has not hardened sufficiently, there is evidence that the sand or fine aggregate is at fault.

V—Flow table test for determining the setting time of cement

It will be advisable to ascertain the setting time of the particular brand of cement in use. This is done by means of a "flow table." This apparatus consists of a table about 30 inches diameter mounted on a shaft which, by means of a cam on a

horizontal crank shaft, is raised and allowed to drop freely a distance of ½ inch (see drawing attached). A mass of concrete moulded in the form of a truncated cone 4 inches bottom diameter 2 inches top diameter and 3 inches high is placed on the table and jolted 15 times. The bottom diameter of the mass is then measured and its relation to the original diameter express the degree to which the concrete has flowed. For the determination of the setting time a series of truncated cones is moulded and jolted on the flow table at intervals until the time arrives when the concrete does not spread or increase in diameter. The period between this time and the time of moulding is said to be the setting time.

Having ascertained the setting time, the Engineer shall allow a large factor of safety, and shall within the time so fixed complete the laying of each batch. The time to be taken for fully laying each batch should commence from the time the water is added and should end when the final punning is completed. This period must be well within the limit fixed by the Engineer and shall in no case exceed 20 minutes.

VI—Test for determining the void percentage of the coarse aggregate.

For this, take a cylindrical drum with walls and bottom not likely to be distorted when filled with the coarse aggregate. The cubical contents of this drum should be carefully calculated either from measurements or by pouring in water of known measure. The drum is placed on a truly level ground and is filled in with coarse aggregate in layers of about six inches and is well shaken at each stage. The surplus at the top should be struck off by drawing across it a flat wooden straight-edge. Water is then poured into the drum from measures of known cubic contents till it is completely filled and is on the point of overflowing. The void percentage

$\frac{\text{Volume of water}}{\text{Volume of drum}} \times 100.$

ANNEX C

The maximum quantity of mixing water per bag of cement shall be six gallons, which amount shall include the free water carried by the aggregate. The following corrections shall be made to this quantity of water:

Approximate quantity of free water carried by average aggregate

Condition of aggregate.	Imperial gallons per c. ft of aggregate
Very wet sand	5/8 to 5/6.
Moderately wet sand	About 5/12.
Moist sand	About 1/5.
Moist gravel or crushed stone	About 1/5.

The coarser the aggregate, the less free water it will carry.

If necessary, where the aggregates are extremely dry, a correction in the quantity of mixing water may have to be made for absorption.

Approximate absorption of aggregates

Average sand	1.0 per cent, by weight.
Pebbles and crushed lime stone	1.0 ditto.
Trap rock and granite	0.5 ditto.
Porous sand stone	7.0 ditto.
Very light and porous aggregate may be as high as	25.0 ditto.

PAPER No. B-39.

REPAIR AND MAINTENANCE OF CEMENT CONCRETE ROADS.

BY

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Introduction.—The United Provinces of Agra and Oudh, have the largest milage of cement concrete roads in India and the problem of their maintenance and repair, has been engaging the attention of the engineers incharge of them. Although the first cement concrete road pavements of importance were constructed about twenty years ago, yet this form of road construction, was not taken up in earnest till 1925. Since then, the number of cement concrete miles has been steadily increasing, and so, it is becoming increasingly essential to fix on a suitable practice for the repair and maintenance of this class of roads.

The problem is, however, not so easy of solution as it might appear to be at first sight, because, the data obtainable from the usually scanty records of the maintenance of concrete roads, are, often, insufficient, and, at times, not very accurate. This is partly due to the fact that the expenditure on concrete roads is usually so low that timely repairs are liable to be neglected and it may not be considered worthwhile to keep a separate and accurate account of the expenditure. Then, differences in the conditions of the road traffic, natural and climatic conditions, kinds of materials available and their suitability, nature of sub-grade, etc., necessitate variation in the details of the practice. Still, it is considered to be advisable to place before the congress a practice followed in the United Provinces, with a view to invite helpful criticism and discussion.

2. *United Provinces Conditions.* It may be pointed out that the cement concrete road-pavements constructed in the United Provinces are generally of unreinforced cement concrete, and the heavy traffic to which they are subjected, consists, almost wholly, of bullock-carts, with wooden or iron-tyred wheels, usually the latter. In summer, the concrete has to stand a temperature of about 120 degrees Fahrenheit and in winter, the minimum temperature is a little above the freezing point. The diurnal variation in the temperatures is about 40 degrees Fahrenheit, causing excessive temperature stresses in the concrete pavements, and, in the case of thick slabs, the difference in the temperatures of the top and bottom surfaces would be appreciable.

The pavements are constructed mostly on sub-grades formed by shaping the existing road bed, consisting of water-bound stone macadam or kankar, compacted by years of traffic, and so, the foundation is generally very firm. It is, however, not implied that the road will be immune from the effects of subsoil movements and the stability factors of soils, effects of variations in the water-content of the soil, etc., if one or more of these be appreciably operating.

3. *Wear, Repair and Maintenance:*—The word WEAR may be taken to signify all changes that may take place in the section or surface of the cement concrete pavement, in use under the traffic, and REPAIR may be taken to signify the total or partial restoration of the section or surface of the pavement that has been subject to wear

MAINTENANCE may be taken to include all systematic action needed to keep the road surface in a satisfactory state under the prevailing natural conditions and traffic.

4. *Wear of Cement Concrete Pavements:*—The principal wear in cement concrete pavements consists of one or more of the following:—

(*i*) Wear at the joints in the pavement,

(*ii*) Cracks,

(*iii*) Depressions or hollows,

(*iv*) Patches and pot-holes, and

(*v*) General wear of the surface.

In addition to the repairs to the above, repairs are needed whenever the concrete has to be cut out for laying utility pipes across the roads, *i. e.* for water mains, sewers or electric cables.

Before describing the repairs and maintenance of cement concrete road-pavements, it will be advisable to consider the nature of the above wear and examine briefly the causes

5. *Wear at the Joints.*—This is chiefly in the form of depressions at the joints and damages to the arrises, and its principal causes are faulty workmanship, impact of wheels under traffic, and neglect in attending to joint-filling.

In pavements constructed by the alternate bay method, it was very difficult to eliminate unevenness at the joints, specially the transverse joints. The trouble was greater where longitudinal tamping was done. Even in continuous construction, unless special care is taken and proper implements used during the laying of concrete, the tranverse joints are liable to be uneven, the concrete on either side of the joint not being exactly at the same level This causes wear, as due to the impact of moving wheels, specially iron-tyred ones, the arrises are damaged, and a distinct depression is formed at the joint. This wear keeps on increasing, and profiles of the concrete surface taken across joints, have shown that in certain cases, the wear had extended to almost a foot on either side, of the joint.

In the case of longitudinal joints, the unevenness is not felt so much when driving in a motor car, as over the transverse joints, but they ravel and become wider as the action of traffic gradually damages and crushes the edges of the concrete on either side of the joints.

Neglect in attending to joint-filling is instrumental in causing wear at the joints In the hot weather, the bituminous filler is partly

squeezed out and is removed by traffic and so, in the cold weather, when the slab contracts, the joints are no longer full. If they are not kept filled up, the edges are damaged by traffic and gradually a depression is formed at the joint.

6. *Cracks* :—These start, as a rule, as fine cracks in small lengths. Gradually, the length increases, or more cracks appear, having the same general direction as the previous ones. These widen and deepen under traffic. The cracks are usually longitudinal, although sometimes there are also transverse cracks and corner breaks. Often, a crack continues from one slab to the adjoining one across a joint, or it may extend to several slabs and then disappear. If neglected, cracks ravel, and the longitudinal ones present the appearance of ruts in the pavement.

Cores cut over the cracks, have usually shown good concrete, and often the coarse aggregate is found to be sheared showing the excessive stress to which the concrete had been subjected at the crack.

Cracks may be caused in pavements of unreinforced concrete, due to a number of factors, among which may be mentioned the following :—

(*a*) Defective subgrade :—The sub-grade may be weak and not uniformly compacted and, so, it may be more yielding at certain places than at others, and cracks may appear due to the uneven settlement.

(*b*) The subgrade may not be well-drained. There may be water-logging during the rainy season and, so, there may be subsidences causing cracks.

(*c*) Subsoil movements : There may be movement in the soil, as in the black-cotton soil, due to the great variations in the bulk of the soil due to the changes in the water content, and wide cracks may be formed. Where the pavement is constructed directly over the soil, the changes in the stability of the latter may affect the slab and cause cracks.

(*d*) The slab may not be strong enough for the traffic, *i.e.* its thickness may not be sufficient, or its mix weak, or, it may be needing reinforcement to give the necessary strength or in a reinforced slab, the reinforcement may not be adequate.

(*e*) The spacing of expansion joints may not be correct. This spacing has an important bearing on the formation of transverse cracks. Too wide spacing may cause cracks, specially if the pavement be thin. In one trial length, expansion joints were omitted, and in another, they were spaced 33 feet apart. The slab was 12 feet wide and 2½ inches thick. It was found that transverse cracks had developed in both the lengths at intervals of approximately 16 feet. On the other hand, in a 9-inch—6-inch—9-inch slab, no cracks have appeared with 60 feet spacing of the expansion joints (and even with 90 feet, in one case), although the pavements have been under traffic for eight to ten years

(f) Excessive thickness of the insulation layer often causes cracks. In one case the thickness of this layer was found to be well over an inch, (nearly one and a half inches), and the concrete had badly failed under traffic.

(g) If lack of attention to the filling of joints causes percolation of water into the subgrade, cracks may appear near the joint.

(h) The alternate arching and curling of slabs due to the difference in the temperatures of the top and bottom surfaces of the pavement, gradually cause longitudinal cracks in the thick unreinforced slabs. The action is very slow and it takes years for the crack to develop, the period being a function of the traffic as well as the thickness of the slab.

(i) A concrete pavement laid in the cold weather, when it is frosty or a cold wind is blowing, often develops fine surface-cracks.

7. *Depressions and Hollows*:—The concrete in these depressions is, as a rule, in good condition and the surface is unbroken. They are very shallow, $\frac{1}{4}$ inch to $\frac{1}{2}$ inch in depth, and are usually due to defective workmanship. Many such depressions appear after the road has been under traffic for a few months and the top-mortar has worn out.

8. *Patches and Pot-holes*:—These are depressions in the concrete surface varying in depth from $\frac{1}{2}$ inch to 3 inches or so. The aggregate may present a loose and crushed appearance, the concrete looks rough and the edges are irregular. These develop, as a rule, at places, where, due to defective material or workmanship, weak pockets have been formed in the concrete, or they may be the result of normal wear and neglect in maintenance. Too much handling and pulling of the coarse aggregate during laying of concrete, due to which the stone is separated from the mortar and a weak spot is formed by the aggregate with scanty mortar, action of frost on concrete at the time of laying, use of too much water in a mix, neglect in curing, lack of care in sorting out weak stone from the coarse aggregate, are also instrumental in the formation of patches, besides the action of iron-tyred heavy traffic.

Cores cut over patches have revealed an insufficiency of cement mortar in the concrete. If neglected, the patches develop (increase in size) rapidly in thin slabs, as, under the pounding action of the wheels, the thin edges of the patches give way quicker than in the thick slabs.

9. *General Wear of the Surface*:—The surface looks rough and the mortar between the aggregates appears to have receded. The portions subjected to heavier traffic appear to be distinctly hollow or dished. The general wear is due to:—

(a) Normal action of traffic, specially of iron-tyred traffic.

(b) Traffic not being kept spread over the entire surface of the road, and so, there is tracking.

(c) Aggregate not being suitable for the traffic conditions.

(d) Excessive floating of the concrete at the time of laying. This draws too much of the mortar to the surface, and after this has worn out under traffic, the concrete, a comparatively weaker mix, shows rapid wear under heavy traffic.

(e) Action of frost and defects in curing also cause wear in the surface.

10. *Maintenance:*—All systematic action needed to keep the road surface in a satisfactory state, is included under this head, such as systematic patch repairs, filling of joints and cracks, attention to the earthen sides etc.

A well-constructed cement concrete road needs but little maintenance during the first seven years or so of its life, beyond filling of joints and occasional petty repairs to holes or patches that may appear. Sometimes, petty cracks appear and these should be painted. The earthen sides have, however, to be kept up specially in the portions adjoining the edge of the pavement, as depressions form here and, unless attended to atonce, these become dangerous to fast motor traffic or cyclists, besids being unpleasant for all traffic.

Joints should be examined and attended to, just before the out-break of rains, and again, early in the cold weather. Patches and cracks should be attended to as soon as they are noticed.

Earthen sides or shoulders, should be sloped at 1 : 36 away from the road, so that rain water may not lodge on them and seep into and soften the foundations of the subgrade. About the end of the rainy season, the sides should be filled in, where necessary. Where possible, these should be turfed, so that the earth may not be easily cut up under traffic and blown away. Any other cheap stabilising treatment could also be employed.

It is essential to keep careful and systematic records of all expenditure incurred on maintenance. The record should also contain particulars of the concrete pavement concerned, such as length, width, thickness at the edges, spacing of joints, thickness of joints, filler used, rates and kinds of materials used, water-cement ratio, temperatures, curing etc. The expenditure may be classified as that on

(i) Joints,

(ii) Surface, *i.e.* cracks, patches, depressions etc.,

(iii) Earthen sides or shoulders, and

(iv) Miscellaneous,

and a correct record kept.

11. *General Principles and Specifications of Repairs :—*

I—All repairs must be taken up as soon as possible after the wear is noticed.

II—The cause or causes of the wear should be ascertained, if possible, and the repairs should aim at the removal of, or remedying these as far as possible, besides putting right the damage or wear.

III—Joints and fine or shallow cracks and shallow depressions, are to be filled or treated with a bituminous material, such as tar, asphalt, emulsion or cut-back and sanded or gritted. During the hot weather, any (hot) bituminous preparation may be heated and used. Spramex and Socony Asphaltum have been generally used by the writer, while, for joint-filling, emulsions, such as colas, colfix, Proctor's emulsion, have been found to be suitable for use during the cold weather. Coarse sand is suitable, but if a depression has to be made up, 1/8 inch to 3/8 inch stone chips should be preferred.

IV—Depressions, cracks, patches, or worn-out surfaces from ½ inch to 1 inch in depth, may be treated with bituminous premix, prepared with either hot or cold bitumen and stone chips.

Cold emulsion premixes, specially the one prepared with Proctor's 50 : 50 emulsion and stone chips, have been found to be suitable by the writer. They are easier to prepare and handle, but hot asphalt or tar premixes, too, can be used, provided care is taken that the bitumen is not over-heated or burnt, as sometimes happens with the unskilled labour of maintenance gangs With Proctor's premix, the quantity of emulsion used per cubic foot of stone chips is 6 to 7 pounds

The patch is cleaned and painted with a little emulsion, and then the premix put in and tamped. If the surface texture is too open, a little fine grit is premixed and tamped into the crevices. The patch is then covered with fine grit or coarse sand and left for 24 hours. It is then tamped again and opened only to rubber-tyred traffic for a day and then to all classes of traffic.

With hot asphalt premix, the patch could be opened to traffic as soon as the bitumen is sufficiently set, and the quantity of bitumen used per cubic foot of chips is about 3 pounds.

V—Depressions, cracks, patches, worn-out surfaces, exceeding 1 inch in depth, and utility cuts in the pavements, are repaired with cement concrete.

The materials and mix should be, as far as possible, similar to those of the original concrete. The size of the coarse aggregate should be about half the depth of the patch.

The patch should be cut out with chisels so that the edges are vertical for 1½ inches from the surface of the pavement, and all loose, crushed, or weak material should be removed The depth of the patch should not be less than 1½ inches. Its shape does not matter, as long as there are no such angles where cavities may form when the concrete is laid. If the surface of depression be smooth, it should be roughened with a chisel.

The surface of the patch is then thoroughly scrubbed with a wire-brush using plenty of water and all fine particles that may be adhering

are washed out. All water in the patch is then mopped out. The surface of the patch is then brushed with a fairly thick (cream like) slurry of rapid hardening cement, and this is left for a few minutes to be a little tacky.

Concrete is then put into the patch, and is well tamped against the bottom, as well as the sides and left a little proud of the surface. It should then be left for about 40 minutes so that it shrinks, when it should be tamped again to fill in the patch. It should be left for a further half an hour and then tamped again with an iron-shod tamper, the surface struck off level with that of the adjoining concrete, and covered with wet sacking. It should be covered with wet sand in the evening and this should be removed on the fourth day and the patch opened to traffic. Alternatively, the patch, when made, might be painted with an emulsion and then covered with sand and left to harden for 4 days and then opened to traffic.

The principal features of this treatment are

(i) the use of a cement slurry tack coat, and

(ii) tamping of the concrete, so that as much as possible of the shrinkage in setting is taken up, so that no cracks appear at the edges of the patch later on.

VI—For a worn out cement concrete road surface, a renewal coat of cement concrete should be given. The existing surface should be well-cleaned and washed and a 2-inch coat of cement concrete laid over it, applying cement slurry just before laying the concrete. The slab may be reinforced, if it is necessary, to give it additional strength. The writer has tried this form of resurfacing on a worn out concrete pavement. The results are, so far, satisfactory.

12. *Repairs to Wear at Joints* :- The old bitumen on the surface of the road is scrapped away, and the joint filled with bitumen and blinded with coarse sand. The bitumen should not be spread on either side of the joint. When the depression is not shallow and causes a bump, stone chips may be used, sometimes with advantage, to form a carpet and reduce the depression. Where the edges of the concrete at the joint are not at the same level, some improvement can be effected by chiselling and rubbing with carborundum.

13. *Repairs to Cracks* :—The cause or causes of the cracks should be ascertained and, if possible, remedial measures taken to prevent further cracking. It is often possible to improve the drainage, and as cracking is often due to the neglect of proper drainage, this should always receive attention.

When cracks in thick slabs are due to subsidence of the road bed, it is possible sometimes to improve matters by jacking up the concrete pavement, (by tunnelling underneath) and supporting it on timber and then carefully making good the subsidence with good earth, (stabilised, if possible). In America and other places, the mudjack is sometimes used for the purpose.

In roads that have been widened before the construction of the cement concrete pavement, there is, almost always, longitudinal cracking

over the joints of the old and the widened portions of the subgrade. Sometimes, when the crack is fine, the edge can be jacked up and cement grout introduced underneath (under pressure.)

Cracks should be painted with bitumen as soon as they are noticed and fine sand sprinkled over it. The paint should be renewed as it wears out under traffic, in 4 to 6 months. If due to neglect or other causes, they have become wide, but are not over 1 inch in depth, bitumen grout or bitumen premix should be filled in them. The premix repair is a good make shift treatment and will last well for about a year, when it may need repairs or replacement.

For deeper ruts or where the concrete is breaking, proper patch repair should be done as given in paragraph 11 above.

14. *Repairs to Depressions and Hollows*:—Depressions less than ¼ inch in depth need not be treated, if the surface is not broken. When the depth exceeds ¼ inch, the surface is not broken and the depressions are not abrupt, ½ inch deep hollows too, may sometimes be left as they are. If, however, the surface shows signs of breaking, it should be painted with bitumen and gritted.

For deeper hollows, premix or cement concrete may be used as already pointed out.

15. *Repairs to Patches and Pot-holes*:—When shallow, painting with bitumen will do, and bitumen premix is to be used when they are deeper. Ultimately, however, it will be necessary to use cement concrete. The technique of the repairs has already been described.

16. *Repairs to General Wear of the Surface*:—When the surface is generally worn out due to normal wear or any other cause, the pavement needs renewal with cement concrete. At this stage it is necessary to consider if the slab needs strengthening also. It will be advisable to test the concrete by cutting out cores and testing these for compression.

A concrete, giving not less than 3500 pounds per square inch, in compression is usually good concrete. If the coarse aggregate be weak, a harder and better stone may sometimes be better to use in resurfacing.

If there has been excessive cracking and no cause is apparent for this, it will be advisable to reinforce the renewal coat with ¼ inch steel bars placed at 12 inch centres both ways, or with B.R.C. fabric or some other (mesh) reinforcement

The surface should be thoroughly cleaned, all crushed or loose material removed, and it should then be washed well, before cement slurry and the concrete are applied.

17. *Repairs to Cuts in Cement Concrete Pavements*:—The filling of the cut should receive special attention, so that it may not subside later on. The filling should be done in layers of 4 inches and every layer watered and well-rammed. Water-bound macadam should form the top layer of the filling, (or whatever existed there in place of water-bound stone macadam, such as, kanker or brick ballast). The trench should be, as a rule narrower

than the cut in the concrete by about 12 inches. In deep cuts the concrete may have to be cut wider, unless tunnelling be easier and less expensive.

The cut should be repaired as desciibed for patches, in paragraph II above; it will, however, be advisable to reinforce the slab at the bottom, and preferably both at the top and the bottom, with 3/8-inch steel bars at 12-inch centres both ways.

18. Concrete roads are expensive in initial expenditure, and so, it is vitally necessary to exercise all care and take every possible precaution during their construction to ensure good materials and workmanship. With these, and an adequate section and good foundations, a concrete road must last very long, and prove the most economical construction for the traffic and other conditions; but having attended to these, the engineer ought not to consider his duty done. Prompt attention to all wear pays many times over, and this is as necessary in a cement conciete road pavement as in any other road-surfacing.

Profiles of the road taken at intervals at the places of wear, *i.e.* joints, cracks, patches etc indicate the wear much better than other records. A simple and satisfactory profil-o-meter can be got made easily and costs only a few rupees. It is quite satisfactory for all ordinary purposes of the road engineer, and useful profilographs may be taken with it.

A core-cuttin machine is another very useful implement for the concrete engineer. It is, however, expensive, but in veiw of the information that it is possible to get about the concrete road with its help, the writer would recommend it to biother engineers.

19. In January 1937, the writer had witnessed some coment concrete road work, which was being done on one of the roads of Bombay by the Bombay Municipality. In this work, a thin wearing course of concrete was laid over the main body of the concrete base, but a cleavage plane was introduced by the use of Hessian cloth, so that, if worn out, the wearing course could be easily removed and replaced probably by a similar wearing course. The writer has not been able to obtain information about it, but thinks that it would be too early yet to expect any wear. The method has been used elsewhere outside India, and is spoken of as successful. The writer has, however, not had any occasion to use it.

DISCUSSIONS ON PAPER A—39 AND B—39

Mr. W. F. Walker (Author of Paper A-39) :—I have inspected recently some six miles of thin cement concrete trackway on the Sitapur-Bahraich Road near Biswan. It was found that *kankar* did not last long here under the heavy sugar cane traffic which this section of road has to carry from November to March. Therefore, cement concrete tracks $3\frac{1}{2}$ inches thick and 2 feet wide were laid over 6 inches *kankar* foundation. The cost of the tracks alone was nearly Rs. 8000 per mile. This is expensive and at the moment details of cost are not available. The cost of materials was very high, stone being nearly 40 rupees per 100 cubic feet. Some of these tracks have been down for two years and they are very satisfactory.

In addition to laying the concrete tracks, the road was also widened to 16 feet to take two lines of bullock carts. The loaded carts use the concrete tracks, and the returning unloaded carts are supposed to use the widened *kankar* road. Actually when I inspected the road all traffic was using the tracks and the *kankar* was used only for passing purposes. I understand that during the heavy traffic season there is one continuous line of heavily loaded sugar cane carts on the tracks so that returning empty carts are forced to use the *kankar* portion. Neither portion of the road shows wear after 2 years.

In another section of the same road a short length of concrete track has been laid down the centre of a 12-foot wide *kankar* road and this also is quite satisfactory.

As saving on capital expenditure is the main reason for using cement concrete tracks instead of a full width concrete road, and saving of maintenance is the reason for laying concrete tracks instead of the waterbound road, therefore, the metalled width should be kept to a minimum.

In most cases, 9 feet would suffice allowing, say, $1\frac{1}{2}$ feet outside the tracks, to protect the concrete and to allow traffic to get on and off the tracks easily. Of course the road between the tracks should be metalled for the same reason.

Unless the concrete tracks are laid on a good foundation they should be thicker than $3\frac{1}{2}$ inches.

Since writing my paper I have found a file containing annual reports on the cracks which have occurred in the concrete roads near Benares.

After periods ranging up to 13 years, some 50 per cent of the slabs have cracked in about 14 miles of road. Approximately 75 per cent of these cracks are longitudinal and are more or less continuous down the centre of the road.

These cracks appear indiscriminately in slabs 20 feet wide or 12 feet wide; in thick slabs or thin slabs; in slabs 33 feet long or 14 feet long; in slabs plain or reinforced. They were first noticed in mile 417 of the Grand Trunk Road in 1931 some two years after the concrete had been laid. Some of these cracked slabs are reinforced. The cracks have

increased in number more rapidly as the years have passed. Mile 413 of the Grand Trunk Road showed no cracks in 1937 after 9 years of service. By 1939 some 40 per cent of the slabs had cracked.

Another adjacent section under perhaps heavier traffic has 18 per cent of its slabs cracked after 13 years. From the facts so far ascertained it is difficult to arrive at definite conclusions as to the causes of these cracks. Practically all the slabs so far considered were insulated from the subgrade by a layer of sand and in only a very few cases were expansion joints provided. Since 1937 about 1½ miles of 6 inches—4 inches—6 inches road have been bonded to the surface in Benares by omitting the insulation layer of sand. Of the slabs so made, 6 per cent have cracked in 2 years. Five furlongs of similar bonded concrete were laid in mile 424 of the Grand Trunk Road in 1937 and 25 per cent of these slabs show small longitudinal cracks some 2 to 3 feet from the edges of the road. As the foundation had been widened for 2 feet on either side before concreting the road, therefore, these cracks are probably due to the settlement of the widened concrete.

It should be noted that the twenty odd miles of thin concrete slabs which are bonded to the subgrade show fewer cracks than the thicker slabs which were insulated from the subgrade. However, it is too early to say that this freedom from cracking is due to the bonding. Personally I think this is the reason. Since 1938 we have been bonding the thin slabs to the subgrade and providing more expansion joints and I think this will keep down the number of cracks very considerably.

Mr. Mahabir Prasad (United Provinces) :—Paper B-39 was written by Rai Bahadur Mukerjee with a view to invite the attention of the Road Engineers to the problems connected with the repair and maintenance of Cement concrete roads, as such roads are steadily growing and their milage is bound to increase with time, not only owing to their suitability for heavy traffic and their low maintenance cost, but also due to the fact that in many cases suitable cement concrete pavements can be constructed at an initial cost not much higher than that of other forms of road pavements at present employed.

It is not claimed that the paper covers the whole ground. It does not include, for instance, all the more important causes of cracks in concrete pavements and all forms of wear. Most of these have, however, been given and the writer would welcome the mention of others, of which his brother engineers might have had experience and which they regard as important.

The writer has not given any figures for maintence expenditure of such roads, and has not included or suggested any forms for keeping records of work and expenditure, as such matters of detail are variable in different parts of the country. Any simple and easily intelligible form could be used.

It was his intention to include photographs of the different kinds of wear mentioned in the paper and he offers his apologies for not being able to do so.

With this introduction, the paper is presented to the members of the Congress for examination, discussion, constructive criticisms and suggestions.

Rai Sahib Lala Fateh Chand (Bijnor):—I wish to enquire of Mr. Walker whether he has tried Bonded Brick Concrete Roads having a wearing coat of 1½ to 2 inches of cement concrete, as advocated by Mr. A. K Datta and if so with what result ?

Another point is about the composition of the slabs. Whether the lower layer is of 1 : 3 : 6 proportion and 1½ inches thick and the upper layer of 1 : 2 : 4 proportion and 2 inches or 1½ inches thick ? I think it is the wearing surface that matters, and not the lower layer of the slab so much, when the sub-grade has been consolidated by the traffic for long time. I would also like to know whether uniform section is still considered good. Most of the roads in the United Provinces have been constructed with edges thicker than the centre.

The third point is whether the author would like to prescribe greater thickness for greater intensity of traffic. Whether it is desirable to have a minimum thickness of 3 inches. Whether it should be so on the metalled trackways in sandy areas.

Another point which was discussed this morning was about insulation layers. I wish to know whether there should at all be any insulation layers, and if so whether they should be of sand or of paper. If there is to be any, I personally prefer that of paper. However, I would like to know the views of the author on this point, in the light of the experiments carried out by him.

An important point on which I would like to have the views of the author is about the expansion joints, their thickness and the material best suited for the same. Would the author say what he considers the maximum length of bays ? I think that bays should not be more than 50 feet in length.

I would also request the author to enlighten me on the width of road to be taken up at one time. I think 16 feet is the maximum that we can do at a time.

Mr. J. C. Hardikar (Hyderabad-Deccan):—I should consider paper, A-39 a very useful contribution and of great interest to constructional Engineers, in these days of financial stringency. The main obstacle to increasing the length of cement concrete roads has been its almost prohibitive cost. A solution in the shape of thin concrete roads has been offered. From this standpoint, I should request the author to supply more information on the following points.

The important point which strikes one on going through this paper is that satisfactory results have been obtained with thin slabs of 3 inches uniform thickness costing somewhere about Rs. 22-4-0 per hundred square feet.

According to the pamphlet of Notes on Works issued for the tour of inspection in the Thana Division on the 9th December 1939, it is seen that various types of Asphalt roads, 2½ inches thick cost somewhere between Rs. 21 to Rs. 23 per hundred square feet.

The initial outlay of the above two types being practically the same, longer life, low maintenance cost and better riding qualities, would incline one in favour of the 3 inches uniformly thick cement concrete slabs.

Consequently I should request the author to enlighten us, in more detail about the wearing qualities and intensity of traffic on these 3 inches thick cement concrete slabs.

I should particularly mention here that terms with respect to intensity of traffic are generally very loosely used. Describing traffic as 'light' or 'heavy' conveys no definite idea to form a correct judgement of the wearing qualities. It would be very useful if the author gave intensity of traffic in tons passing per 24 hours per yard of surfaced width.

From the paper it is noticed that these thin slabs 3 inches thick were first tried in 1931-32. Even 2 inches thick slabs were tried in 1931-32. Statistics as regards their behaviour for the past seven years and intensity of traffic they could successfully withstand would be very interesting.

Insulation layer is one of the points which many members have touched. The paper mentions that in the light of experience, the insulation layer should be entirely omitted and "every effort should be made to bond the concrete to the sub-grade." It is also stated that "there are very few cracks of any kind in the bonded slabs, while there are numerous cracks in the insulated slabs both thick and thin."

The incidence of cracks and "large cracks instead of hair cracks" has been attributed to the insulation layer. This I should consider, not very convincing. The insulation layer by allowing a free play for variations of length and shape, due to temperature stresses and other internal stresses should, I think, minimise the formation of cracks. Subsidence of the sub-grade would be mainly responsible for the cracks, and not the insulation layer.

In the data supplied under Appendix I of the paper, cost of mixing concrete has not been given. The reason why it is omitted may be made clear.

Mr. P. V. Raju (Madras) :—I dare say that paper A-39 which Mr. Walker has contributed on the evolution of the thin concrete roads, is a very interesting paper on experiments carried out over a very long period. Still there are several controversial matters in this and the last word has not been said. We still have very different opinions with regard to the question of insulation, whether there should be insulation or not, and if we do have insulation, whether it should be paper or wet sand. Then again there is the question of expansion joints, and what method should be adopted—whether we should adopt mere joints plugged-in with asphalt, or whether we should provide steel rods embedded in concrete to take up the cantilever action, or whether we should insert copper sheet in slabs and fill in the top with asphalt. There is also the other controversial subject, whether the slab should be uniformly thick or should be thicker at the edges and thinner in the middle. There is no finality about these. I would recommend that this subject be gone into in more detail by the technical sub-committee, by issuing a sort of questionnaire to all the Provinces and collecting information on the same lines as I suggested this morning. For example, the author had experimented in 1927-28 with the sandwich method *viz* 2½ inches stone being covered with a 1 : 2 mixture of sand and cement 1 inch thick, with 1½ inches metal at the top and also in Rollcrete and Colloidal Concrete and found them to be unsatisfactory and came to the conclusion that no half-way measures

were economical and good. I find that in the Madras Presidency we are carrying out these experiments on a road this year. Is it not a colossal waste? If we had the results of these experiments and seen how unsatisfactory they had proved so long ago, surely we would have taken advantage of those results.

Another observation he makes in his paper is that vibrated concrete 1 : 3 : 6 has cost as much as 1 : 2 : 4 ordinary concrete, and the initial cost did not justify its use. But we saw only the other day at Poona, that costly Danish Machinery was being used for laying and vibrating the concrete in the all concrete road that is being laid from Poona to Bombay. But there was the doubt expressed whether that was going to be cheaper than hand-tamping or not. It seems to me that instead of going on indefinitely discussing about these things, we should issue a definite questionnaire on all these questions, send it to all, get all the opinions and consolidate them, and then we will have something like a majority opinion on the subject.

Mr. M. S. Duraiswami Ayyangar (Travancore):—I have read with particular interest paper A-39 by Mr. Walker, regarding the evolution of thin concrete roads in the United Provinces, and our thanks are due to him for recording therein his many personal experiences in the making of concrete roads, one stretch of which is at present the longest continuous length of concrete road in India. My special interest in this paper is because I am at present engaged in the construction of what will, when completed beat the present record and turn out to be the longest continuous length of cement concrete road in South India, if not in all India. It is projected to cement concrete 47 miles stretch of road from Trivandrum to Cape Camorin and tar-crete the balance 7 miles with 1½ inches carpet. About 17 miles of this length will have a section of 5 inches—4 inches—5 inches and the balance 30 miles 4 inches—3 inches,-4 inches. It, therefore, just passes the limit laid down by Mr. Walker for a thin concrete road; but I do not think that I can lay claim that it is a very thick section. The roadway is to be only 14 feet wide with water-bound macadam side berms 4 feet on either side so that the total width of traffic way will be about 22 feet. The work was started about 3 months back and we have so far done about 7 to 8 miles. The contractors have agreed to complete the whole length including the tar-crete portion within 15 months from the date of start. For convenience in allowing traffic during construction the concrete is laid in two halves each 7 feet wide, with the respective side berms 4 feet wide, done up before the half is opened to traffic. As I have just started this work of so much magnitude, costing about Rs. 14 lakhs including reconditioning of the sub-grade, this paper dealing with the experiences of similar work done in the United Provinces is of very great interest to me, and I should like to profit by the author's experience. Mr. Walker has assured us that inspite of some bursts which occurred in his thin concrete road, it is not a failure. I therefore, request the author and others as well who have done similar work to clear certain points relating to the work I have on hand.

I found it was practically impossible to divert the traffic in most sections of the road as the original metalled width has all along been only 14 feet. The existence of rice fields on either side of the road in portions which are in embankments in certain sections adds to our difficulties. I have, therefore, been forced to do the work in halves, leaving the other half free to carry the traffic.

The essential object of thickening the edges of a concrete road is I presume to make it withstand the impact of a heavy load passing near the edge. If this is the object, there must be a thick edge by the side of every joint. In laying the concrete roadway in two halves, we make a longitudinal joint in the middle with the thin section *viz.* 3 inches of a slab on either side of the joint. When heavy lorries or hand carts pass over such a thin section, it is not impossible that the slabs break up at the corners of the longitudinal and transverse sections where the pressure of the carts bears most. The Concrete Association of India have, in view of this, suggested the use of longitudinal shear bars, located at a distance of 6 inches from the centre of the joints in the middle of the slab, so as to resist the stresses which are brought to bear on this thin section of concrete slab. I note that none of the roads which we have visited during the last few days or in any of the roads which have been dealt with in the papers which are now before the meeting, this system of using shear bars has been followed. I would, therefore, like to know the opinion of the members of this Congress regarding the utility of the use of these shear bars. As an alternative to the use of these shear bars, it has been suggested to me that a uniform thickness of slab, say 3½ inches in place of 4—inches—3 inches—4 inches and 4½ inches in place of 5 inches—4 inches—5 inches section can be substituted in place of the varying section now adopted without materially altering the cost. A relative study of the comparative merits of the uniform slab with that of the thickened edge with shear bars in the middle will be of great help to me.

Another problem which I would like to have your opinion on is regarding the utility of an insulating layer between the existing road surface and the new concrete layer which we are putting on. Mr. Walker has said that in the case of thin concrete slabs, bonding is a definite advantage. Whether my road is to be classed thick or thin is a matter of opinion. It is just on the limit. I may, however, inform you that our road has been a metalled road for over 60 years and has a good soling of about 1 foot thickness of successive layers of consolidated metal. Whether, therefore, it is necessary to insulate the concrete layer over such a hard base appears to be a matter for deep consideration. At present a thin layer of sand, ¼ inch to ½ inch thick, is being used to serve as insulation. I should like to know whether this is at all necessary as, after reading Mr. Walker's paper, I am converted to the opinion that such insulation is not necessary.

The third point on which I have my doubts is regarding the provision of dowel bars at the junctions of the transverse joint of the road. This has also been discussed in some detail. Personally I think that if a ⅜ inch spacing be allowed between successive slabs and this is filled up by asphalt, either prepared in advance or laid *in situ*, I do not see that there should be any further necessity for using these dowel bars. What purpose these exactly serve during the construction and expansion of the slabs is a point about which I do not feel quite clear, and I should like to get further elucidation on their utility. Mr. Kynnersley mentioned that they are intended to take the thrust brought to bear on them and act as cantilever. From what has been said by Mr. Walker in his paper, the 'bursts' have extended to about 7 feet to 8 feet from either side of the joint. In that case the cantilever bars or the dowel bars should be atleast 10 feet long in order to withstand that stress. It cannot act as a

cantilever, otherwise it cannot take up the stress which is brought to bear on it. Our bars extend only to 2 feet on either side.

Another use of these dowel bars is across longitudinal joints of the cross lanes of traffic. In a narrow road, for example which is only 14 feet wide, as in my case, the traffic must necessarily cross from one side of the road to the other, and, therefore, pass over the joint. There should be a certain amount of stress by the passing of the traffic from one side to the other. So whether or not it is necessary to provide some dowel bars to protect these longitudinal joints is also a point on which I should like to have the opinion of the members. Personally I feel that the dowel bars are more useful in narrow roadways across longitudinal joints than on the transverse joints.

(At this stage the discussion was adjourned till the next morning).

Tuesday, December 12, 1939.

DISCUSSIONS ON PAPERS A—39 and B—39.

(Continued)

Rai Sahib Hari Chand (New Delhi) :—In the Paper presented by Mr. Walker, there is one point on which I want to seek further information. On page 2 of the Paper, Mr. Walker gives the cost of maintenance of a concrete road, such as the one dealt with by him, as Rs. 5/- per mile per annum. In the first place, he has not given the width of the road ; so, this information does not carry any meaning. Will he please give the width of the road on which this estimate is based ?

In the second place, a sum of Rs. 5/- is not enough for maintenance. As far as my experience goes, the cost of maintenance consists of painting the joints at least once a year before the rains, and the cost of this alone when the width is twenty feet, comes to Rs. 30/- or Rs. 40/- per annum. So, Rs. 5/- as estimated by Mr. Walker is not adequate. Painting and filling-in the joints requires 2 hundredweight of asphalt material, 100 cubic feet of sand and some labour. So, will Mr. Walker throw more light on this point ?

Mr. S. K. Ghoso (Bihar) :—I want to know, from those of you who may have tried it, what is the effect of mixing lime with cement in cement concrete road work. I would also like to know if there has been any cheaper cement concrete road than the roads built in the United Provinces.

Mr. Syed Arifuddin (Hyderabad-Deccan) :—Mr. Walker in his paper has given very useful information, and it certainly opens up a wide field of utilising cement for road-making.

As the author thinks that the insulation is actually harmful and that bonding is necessary, I should like his opinion whether he considers it advantageous from his experience to lay a 3-inch metal coat on the old surface, grout it with cement and sand after it is consolidated, and put on the 3-inch cement concrete immediately after grouting. This will increase its effective thickness to slightly greater than 3 inches and the bonding will be more effective. I should further like to know whether he has laid 3 inches or 4 inches cement concrete on newly consolidated metal surface before it was subjected to traffic, and if so, with what result.

If the bonding proves advantageous, as it appears to be it is difficult to justify the necessity of expansion joints in the bonded cement concrete at least at so close a distance as 33 feet. It seems to me that, in the light of this information, we shall have to overhaul our idea of the nature of temperature joints. It would require some further investigation in the matter. I would suggest to Mr. Walker that while making new cement roads bonding the cement concrete to the metal below, he may do away with expansion joints for a length of a few hundred feet and see what happens. Cracks wherever they appear can be treated afterwards.

Dr. M. A. Korni (Calcutta) :—I am not concerned at present with road construction, but I have always been extremely interested in the continuous growth of modern methods of road-making. During a trip through Italy by car, I noticed that many of the *Autostradas* are built of thin concrete slabs. Upon investigating, I learnt that different scientific methods are used for making these road slabs. Two of these methods which I remember I would like to put before you for experimental purposes.

A slab measuring 3 metres by 3 metres of about 65 millimetres in thickness was built. The corners were heavily reinforced and the centre of the slab only slightly so.

The second method made the use of a slab of the same dimensions reinforced with very thin high tensile wire, highly pre-stressed. The slab was cast, cured and possibly after the cement concrete attained a reasonable strength, the wire was released. The Italian road makers claim that these slabs were undamaged for several years. There is, of course, no bullock-cart traffic on the *Autostradas* or on first or second class roads.

Mr. N. Das Gupta (Calcutta) :—Mr. Mukerjee has not definitely recommended any grade of asphalt for joint filling probably because he considers, like many other engineers, that anything may be used for joint filling. But I must say that this is not the case. There are some particular grades of asphalt which are particularly suitable for this purpose and have been satisfactorily used in Bengal over a long period.

As will be apparent from Mr. Mukerjee's paper and as it is really the case, the joints in cement concrete are the weakest points. We have already seen on the Marine Drive and elsewhere, any bituminous product used other than the particular grade of asphalt is liable to be worn out rapidly by the combined action of traffic and heat We can now analyse the requirements of the joint filling material in the following way :

(1) It must allow for expansion and contraction of the adjacent slabs.

(2) It must be strong enough to resist the super-imposed load and blows of traffic.

(3) It must not melt at the highest temperature to which it may be exposed.

The correct grade of asphalt which fulfils these requirements is an air blown or oxidised asphalt of 8 to 15 penetration, containing 99.8 per cent bitumen and having a melting point of 240 degrees Fahrenheit. I believe if this material is used, much of the trouble experienced at the joints will be largely eliminated.

The question now arises whether this should be used neat or with sand and aggregate. This will depend upon the width of the gap. It is desirable to have as thin joints as possible, and for such cases neat asphalt should be used for efficient filling. For wider joints or for repairs to widened joints, it is desirable to use a mastic of the following composition by weight rather than neat asphalt for greater strength:

Sand	40 per cent
⅜ inch to ⅛ inch stone chips ..	22 per cent
Portland cement ..	18 per cent
Asphalt	20 per cent

This mastic is prepared by heating the aggregates and the asphalt separately in half-cut drums to 375 to 400 degrees Fahrenheit and then mixing and laying the mastic at about 350 degrees. If found necessary, a coat may be given by a 60 per cent solution of this asphalt in kerosene oil at ordinary temperature. This mastic may also be used for all patch repairs in the cement concrete

In 1937, an experimental stretch of such mastic was laid in Calcutta on the approach road of the Howrah bridge, to ascertain its strength under heavy bullock cart traffic, and the results have been quite satisfactory. It is necessary to keep the finished mastic surface about ½ inch proud. No rolling is necessary; the mastic hardens on cooling and traffic may be allowed when the mastic cools down to the atmospheric temperature.

Rai Bahadur Mukerjee has mentioned that concrete roads should have good foundation and has suggested tunnelling and making good the subsidence with good earth. I doubt whether this would be an effective remedy, as the concrete slab will still have loose earth underneath, and so this would not have a good bearing. Though without any experience of this sort of work, I think it logical to strengthen such bad soil by piling in the following way, *viz.*, to drive piles 6 feet to 10 feet length and 2 inches minimum diameter along a line 6 inches to 1 foot away from the edge of the slab and at an angle of 45 degrees. The spacing of piles may be 6 inches to 1 foot, depending on the condition of the road. These piles would pack the earth under the slab and give an upward thrust, which will be able to resist the load of the slab itself *plus* the traffic load with impact. Also, the piles will themselves take some load and offer resistance against settlement of the slab.

For very porous soil, where there is danger of water percolating under the slab and thus causing settlement, Rai Bahadur Mukerjee has recommended proper draining of the berm. But I believe the more effective remedy would be to waterproof the soil under the slab by pouring 50 to 55 per cent asphalt emulsion, diluted if necessary, along the edges of the concrete slab. The porous soil would readily absorb the emulsion and be waterproofed for a distance of about 6 inches to 8 inches. The portions beyond this distance are protected by the slab itself and would not, therefore, require any treatment.

Mr. Jagdish Prasad (Government of India) :—On page 7 (*b*), paragraph 1, Rai Bahadur Mukerjee recommends that fresh concrete used for repairing patches and worn out surfaces exceeding 1 inch in depth should be tamped three times, the second and third tampings being done at intervals of 40 minutes and 30 minutes respectively. I wonder whether this kind of tamping would not upset the setting of the cement and result in a comparatively weaker concrete.

In order to overcome the difficulty of bonding the new concrete to the old, it becomes necessary to use a fairly sloppy mix, but the more water there is in the mix the greater is the shrinkage. The only solution of the problem of satisfactory patching appears to lie in using very dry mixes and compacting or rolling by vibration.

In certain States of America where patch repairs are done in the ordinary way, the freshly laid patch is treated with a mixture of hot linseed oil and turpentine in the proportion of 1 to 1 and then covered with a lead and oil paint.

Mr. A. Lakshminarayana Rao (Madras) :—It may be seen from Mr. Walker's paper that about 100 miles of concrete road of various thicknesses were constructed in a period of 10 years, the cost ranging from Rs 64 to Rs 22-4-0. The costs as given for 100 square feet seem to be deceptive: Rs. 64 and Rs. 22-4-0 are no doubt very low figures, but if the total amount that has been spent on these concrete roads is calculated, it will come to a figure of about 40 lakhs of rupees. And after spending 40 lakhs of rupees, they have been able to improve about 100 miles of road in the United Provinces. At this rate, how many years would it take to treat with cement concrete all the important roads of the United Provinces and how much money would it cost? I would request the author to enlighten us whether cement concreting was done as part of a definitely laid out programme, and if so, how many miles the programme covers, in how many years it is proposed to complete the programme and at what cost? I believe that in the United Provinces there are at least a thousand miles of roads which are important Is it the idea of the United Provinces Government and engineers to solve the problem of their roads by treating with concrete, all these 1,000 miles, and if so, where do they expect to get the colossal amount from? The author will kindly enlighten us on the point whether the work so far done is part of a definite programme. Otherwise, it will be only an exhibition of the capacity of the road engineer to show a good road provided a lot of money is given to him and not a proper solution of the road problem of the country. We shall not see the completion of the programme; even the next generation of engineers may not see the thing completed at this rate of progress. I ask this question

because the problem before us is not one of laying down a good road, provided we are given whatever money we want, but one of selecting and evolving that kind of road which our finances would permit us to construct for all the roads and which would be better than the water-bound macadam road, which we find has been failing miserably under the fast pneumatic-tyred traffic of the present day.

The author refers, on page 7 (a), to the concrete road, 12 feet wide, laid between Ghaziabad and Bulandshahr between 1935 and 1937. I had occasion to pass over a 12 feet width of concrete road near Benares in a car and I found that the same was too narrow. When the car in which I was going, had to overtake a bullock cart or to cross another vehicle, it was found that one wheel of the car had to go down on the earthen berm with a bump and get up again with another bump in a few seconds. Fortunately it was dry weather and there was no skidding. I presume it must be a difficult operation in wet weather. When discussing about the width of asphalt roads in Poona, particularly the "conphalt" roads yesterday, many of us had remarked that a 7 feet strip of concrete was not quite sufficient, that the width in the centre should be increased, and so forth. What is the gain in having a road 12 feet wide? Is it found to be useful in practice? Rai Bahadur Mukerjee has confessed in his paper that it is really desirable to have the width increased to more than 12 feet. If so, I would ask the authors kindly to enlighten us as to why they are presisting in 12 feet width of road.

Mr. Walker, on page 6 (a) of his paper, states that four slabs cracked in 1936-37, that is during the last two years of construction, 5 slabs cracked in 1938, and 8 slabs cracked in 1939. It is thus clear that even before the effects of wear become apparent, the slabs are showing signs of weakness in other directions. In mile 424 of the Grand Trunk Road, constructed in 1930, 'some 41 bays seem to have developed cracks up to 1937,' that is in 7 years, though the 'traffic was 650 tons per day,' on a 12 foot road, which is not a very high figure. In the same way, 'ruts 3 feet wide and ½ inch to ¾ inch deep, are said to have been formed in the 6-inch—4-inch—6-inch slabs. The author has stated, on page 7 (a) that these cracks 'appear to be harmless.' But they would surely allow rain water to attack the subgrade and soften it, leading to the development of further cracks. The concrete roads are constructed at a tremendous cost of thousands of rupees per mile. So whether the failure is due to cracks or wear it matters little, for it avails not if the operation is successful but the patient dies of heart failure. The United Provinces are leading the rest of India in the matter of concrete, roads, and I request the authors to kindly state whether the cracks are developing slowly and whether they are the symptoms of a disease likely to develop seriously in future. For concrete roads are very costly, and an engineer has to be cautious before launching on costly schemes. At the same time, I would request the author to state if he is satisfied, as a result of further experience, that a 12 feet width of roadway is answering the purposes of traffic well and a 3-inch slab can be depended upon. The penultimate sentence on page 10 (a) reveals that the author wishes the road to be wider than 12 feet.

The paper of Rai Bahadur Mukerjee shows that the problem of repair and maintenance of concrete roads has already arisen in the United Provinces and is not easy of solution. He does not apparently consider that the cracks are harmless. According to him, cracks, if neglected,

ravel, and the longitudinal ones present the appearance of ruts in the pavement. Cracks are said to be due to defects in subgrades. If so, will not water trickling through the cracks aggravate the evil? The thin $2\frac{1}{2}$-inch slab, 12 feet wide, is said to have developed more cracks than the 9-inch—6-inch—9-inch slab (*vide* page 3 b). If so, is it not clear that the reduction of thickness to $2\frac{1}{2}$ inches to 3 inches is not after all an economy in the right direction?

Then in para 11, item VI, page 7 (b) the author suggests a remedy for a worn out cement concrete road surface. Will he kindly enlighten us if it was actually done in any place? If so, when and after how many years subsequent to the laying of the slab? There are no statistics in the paper showing what it costs for the repairs and maintenance of cement concrete roads year after year. There is a bare account given, but absolutely no facts and figures of the cost of maintenance year after year. I would request the author to kindly furnish us with the figures of the cost of maintenance year after year. In Madras on a stretch of concrete road laid about 4 years back, it has been found that Rs. 25/- per mile is necessary for filling up only the expansion joints. Mr. Modak of the Bombay Municipal Corporation was expressing the view that one of the chief defects of a concrete road is the difficulty of repairing it when the surface gets bad; and this paper by Rai Bahadur Mukerjee seems to confirm his view. It appears, therefore to be necessary that cement concrete roads, to be a success, should be not less than 5 inches thick and 16 to 20 feet wide. They should be used only in localities where the needs of traffic demand such a road. It is uneconomical to use cement concrete for lighter traffic which ought to be tackled with lighter and less costly material, so that the tax-payers' money may be used to the best advantage and the 'road-rupee ratio', on which our President has laid so much stress, may be as high as possible.

It cannot at the same time be denied that for district roads with very heavy traffic and not subject to frequent interference from public utility concerns, about which Mr. Modak has complained so much, a cement concrete road is the most economical and the only one to be adopted in India by Indian engineers.

Regarding dowel bars, I believe we are not designing our slabs as beams or cantilevers anywhere. Therefore, to have something which functions as in a beam or cantilever, does not seem to be quite appropriate. Further, the cracks, as we have seen, appear always at about 8 to 10 feet from the joints and the dowel bars are about 6 feet long; so that, the dowel bars seem to have no connection with the cracks. I would suggest that the best way of dealing with the cracks is to let them alone.

As regards insulation, in Madras a thick insulation of sand, was tried first but later on, this was given up on the assumption that insulation was not necessary. Subsequent experience showed that a thin layer of sand is a very good insulation and a cheap one too. Yesterday, one of the Bengal engineers stated that if sand is used, the coolies may not wet it with water when the overseer is away, resulting in dry sand being used, with dangerous consequences. Water is so cheap in India, and I do not see why it should not be used. It

has been found that sand insulation is the most economical, and I may say for your information that there have been, so far, no cracks on the Madars roads, though they were laid two years back. I confess it is too early to come to any definite conclusion, but I give the information for what it is worth.

Nawab Ahsan Yar Jung Bahadur (Hyderabad-Deccan):—I wish to mention a few points which have struck me after the experience that we have had in Hyderabad Dominions, especially in the City of Hyderabad. As regards Mr. Walker's paper, I quite agree with him that if a thickness of 3 inches or 4 inches is designed for construction over a hard base—an old metalled road—it will be perfectly all right without insulation. But if the thickness is going to be more than 4 inches, insulation is necessary, because then it acts like a slab and can float. In Hyderabad, I have tried 3 to 4 inches bonded slabs a great deal. If this slab of 3 to 4 inches is laid on a surface which has been resurfaced—just to get the old metalled base reformed and rolled with 2 inches of new metal—the trouble starts and cracks appear if the rolling is not done properly. I find from my experience that unless you have a good hard foundation *i. e.*, a good hard base, bonding with 3 and 4 inches of cement concrete is not at all advisable. I shall give you an instance. We laid a 4-inch—3-inch—4-inch bonded coat about 2 years ago on a metalled road which had been freshly consolidated by the contractor for reconstruction. The result was that this portion only was showing more cracks than any of the other portions that were constructed at the same time with 4-inch—3-inch—4-inch coat on an old consolidated macadam road.

This clearly shows that the whole thing depends on what foundation you give to your concrete slab. If there is any danger of a weak base, I would not recommend anything less than 5 to 6 inches thick cement concrete slab. Really speaking, the slabs in Hyderabad have been very successful, and very few of them have cracked where the section used is 9-inch—6-inch—9-inch. As the previous speaker said, if you have money, you might use it in a more useful way by constructing a slab of 9-inch—6-inch—9-inch section if the base is not strong enough That is where the engineer's experience comes in. He must see whether the base is strong; if it is strong, then have the slab 3 or 4 inches. Also if the slab is more than 4 inches thick, expansion joints may be necessary From the experience that I have had for the last 8 or 9 years of cement concrete roads, I may say that the principal involved is not expansion and contraction only. What I find is that if you allow the cement concrete to cool down for a certain number of days, this is all that is required. In the case of a thickness of 4 to 6 inches slab there is not much expansion that you have to be afraid of. What is required is complete cooling of the concrete. If we could cool the concrete quicker say in a day, this would be quite enough. But we generally allow 3 to 4 days for it to cool completely, and then I find that no prefilled expansion joints are necessary. The only thing required is to leave working joints. I simply paint these joints without any filler with three coats of cold "Colas" 50/50 mix. Everything is so simple; no expansion joints are required, and there is no trouble of filling the joints deeply. Moreover, it is very economical and not at all costly even when you have to put on three

coats of paint. In my view; it is not expansion and contraction that we need be afraid of. We must see that the concrete is completely cooled.

This theory has been evolved by American engineers who have constructed some of the largest cement concrete dams in the world. In some of the bigger works they have utilized refrigerators to cool the concrete and then close the expansion joints. I am afraid we use a wrong term; our experience is that it is not due to expansion only that the slabs crack.

Now, as regards maintenance, the cost of Rs 5/- for a road 20 feet wide is much too small. Our roads cost us very little to maintain. In the first year we have to fill the joints—probably twice. After the second year, filling is required only once a year. Formerly we used a filler, but nowadays we are not using it; we are only painting our working joints. That is the best arrangement. For subsequent filling we use cold "Colas" 50 . 50. You will find that if you use 50 : 50 "Colas" you will not be wasting any material. No preparations are necessary as described by one member. Our experience has been that "Colas" 50 : 50 can be poured very easily. You can fill the finest joints and avoid waste. Take a small tin pot and bend the edge over and give it a little point just to pour the liquid and you will find that an ordinary cooly can fill up the joints very nicely. After filling, you sprinkle a little sand and allow traffic over it. That is all.

With regard to the remark about patch-work, our experience during the last 9 or 10 years is that 1½-inch thick cement concrete layer is not at all lasting. It may remain for a few months or a few days, but it will never stand unless you dig up 2 to 3 inches deep and place new cement concrete If you have to deal with a pot-hole, you have to go down to the whole depth and do the patch-work right down from the thickness of the slab.

Mr. Modak, I think, raised one objection against cement concrete roads. He said that they had to take into account the needs of public utility services, which necessitated the cutting up of roads. He said that it was easier to cut up asphalt and join it up afterwards than cement concrete. That is not our experience. It is found that in the case of asphalt you have to keep the surface, when filling up a cut, a little higher than the old surface, with the result that you have a hump on the portion where the cut was made. But this does not happen in the case of a cement concrete road. In Hyderabad, I have found that a cement concrete road cut joins much better than a cut on an asphalt road, the old and the new surface becoming quite level.

Mr. S. B. Joshi (Bombay) :—I only wish to emphasise one point with regard to the thin concrete slab. For a 1 : 2 : 4 thick slab, we use 1½-inch metal, but for a 1 : 2 : 4 thin slab, we cannot use the same metal. We shall have to use ¾ inch metal. Suppose we break the 1½-inch metal into four parts. Then these four pieces have got to be embedded in cement, so that the perimeter of these four parts is 1½ times the perimeter of the big piece. That means that if you use 1 : 2 : 4 thin slab, it has got lesser cement about its aggregate. Therefore, in order to have the same wearing qualities for a thick slab and a thin slab, you must use more cement for a thin slab.

Mr. T. R. S. Kynnersley (Bombay) :—There is one point in Mr. Walker's paper to which I would like to draw your attention for a moment. On page 4 (a), in section 4, he says :

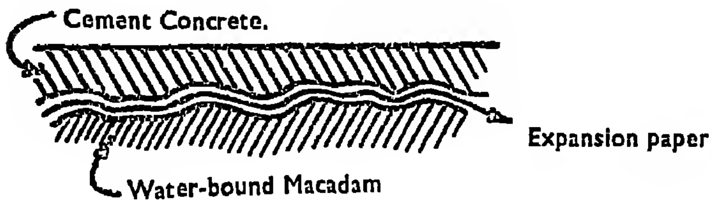
"Innumerable experiments have been tried whilst making these roads and it has been found that satisfactory results canbe obtained using a 1 : 2 : 4 mix laid on good foundations of at least 6 inches of old road crust;"

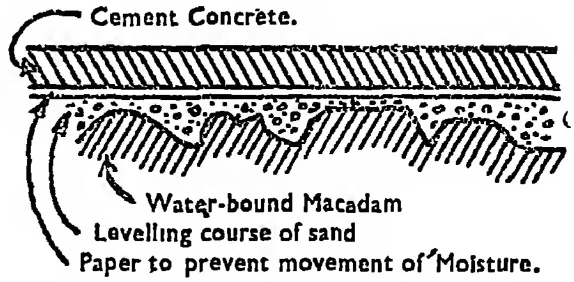
Well, in that he has said what is vulgarly known as "a mouthful". I would like to refer once again to the experience of the Concrete Association. After all, the moment there is a little bit of trouble with concrete roads, it always comes back to Forbes Building. I should like to endorse, with all the power at my command, the remarks made by my friend here, because I think that he really has got down to the bottom of the trouble. It is useless to bond a concrete top to a bad foundation. The Bible says that you 'cannot put new wine in old bottles', and you cannot make a good road by putting good concrete on a rotten bottom. There is a tremendous temptation to do it. You see a road, and the first temptation is to bring along some metal and some sand and some water and roll it, and by the time the road engineer has done his stuff it looks like a first class surface, and you say, "Now we will put a top on it" and you think you are doing a very good thing. Actually, you could not have done worse. I would implore you as road engineers to consider the fallacy of doing that. Make your road up by all means, but leave it to get consolidated by time, rain and traffic, and then, after a time, you can put a top of cement concrete on that. You cannot bond a cement top to a newly made patch-work road and it is fatal to try.

Mr. A. S. Adke (Bombay) :—Rai Bahadur A. C. Mukerjee, has put before us the question as to how to repair a fairly worn out surface. I take for granted that the concrete road has been properly constructed and the defects now seen on the surface, such as cracks, pot-holes, widening of joints, etc., are appearing due to either bad foundation or wear and tear on account of traffic. From the defects visible on the surface, the weak points can be made out. The pot-holes and joints should be repaired thoroughly. The surface will then provide a good foundation, and a wearing carpet of 2 inches to 2½ inches cement concrete should be laid This wearing coat will wear uniformly, as the foundation is strong and uniform.

Mr. N. Durrani (Bellary) :—Expansion joints are being given at 50 feet interval. Assuming an average variation of 50 degrees Fahrenheit, the theoretical expansion may be about a tenth of an inch. As it is, the surface of the water-bound macadam below is not even and smooth to allow concrete to expand freely without obstruction. Even the addition of tar paper does not help one surface to slide over the other as even this will follow the contour of the rugged water-bound macadam below. I suggest first the whole surface be made even to the camber by spreading a course of fine sand and on that the expansion paper laid (see figure below). If concrete is laid on a surface so prepared, there will be free movement and the expansion will take place freely.

Without this precaution, I am afraid the expansion joints will not function at all. It is then a misnomer to call them expansion joints. These are simply working joints.





The next point is about comparative cost of concrete. The chief difference between the United Provinces and Madras is that in the United Provinces the cost of metal is very high as compared to that in Madras. This extra cost is due to great lead in some cases going up to even two hundred miles As in the case of bridges where there is a relation between the cost of deck and a pier for an economical span. it may be possible to arrive at a suitable binder for metal of different costs for giving a most economical riding surface. Cement binder is no good for Laterite or Lime.

I request information, if available, on accidents after construction of modern roads. On good roads, one is tempted to travel at high speeds. Human nature being what it is, we have to take precautions. For this Sign-posts should be provided liberally according to universal standards. Super-elevation must be carefully given to curves, the width of the road should be greater at curves than on straight reaches.

I also suggest standard mile and Furlong stones for the whole of India.

Rai Sahib Hari Chand (New Delhi) :—I must congratulate Rai Bahadur A. C. Mukerjee on the very ably-written paper, which contains most useful and practical hints and tips on the subject of " REPAIR AND MAINTENANCE OF CEMENT CONCRETE ROADS ".

I would like to make a few observations on some important points in the paper.

Expenditure on Maintenance :—The expenditure on the maintenance of Concrete roads is so low that it is almost negligible. It is about Rs. 30/- to 40/- per mile per year excluding, of course, the usual berm repairs. The claim put forward by its advocates that in the case of Concrete road the "First cost is the ultimate cost" is, therefore, thoroughly justified.

As regards wear of the cement concrete pavements, the author refers to "repairs needed whenever the concrete has to be cut for laying utility-pipes across the road *i.e.*, for Water-mains, Sewers or Electric cables."

In this connection I have to observe that with a little foresight this trouble can be eliminated or greatly minimised. Such troubles occur in City-lanes and the following remedies are suggested :—

(a) In the newly developed areas, the best remedy is to segregate all kinds of utility services in the footpath, before concreting the roads, as recently done by the Improvement Trust, Cawnpore.

(b) In the case of old lanes, the remedy is to provide cross-connections at suitable places before concreting the road or providing proper ducts at such points and covering the same with precast Reinforced Concrete slabs. This method has been very successfully adopted in Hardwar Municipality.

Joints :—Transverse joints in Concrete road whether laid by the Alternate Bay method or by Strip method can be made even if proper and frequent checks are exercised in laying by means of straight edges and floating the joint commonly with the one previously laid.

I would also recommend that while approaching the joint, the concrete for about a length of 2 feet should be laid backward from it. This ensures good solid concrete and evenness at the joint.

Cracks :—It has been my experience that defective subgrade accounts mostly for the cracks in a road slab. Even a thin slab can stand well if the subgrade is well consolidated, well drained, and uniformly compact.

I had a bad experience of laying once a 9-inch—6-inch—9-inch slab over an old water-bound macadam in black cotton soil area, which was flooded in rains. Most of the slabs in this portion of the road have since cracked. Deep seepage-intercepting-trenches filled with sand and cinder would have greatly mitigated the evil.

Another contributary cause to form cracks, which perhaps has escaped autor's notice, is that a transverse crack is invariably formed if a slab covers the junction of two counter slopes in the formation level. In my opinion there should always be a joint at such junction of slopes.

As stated by the author in para 8 of page 4 (b), I quite agree that "too much handling and pulling of the coarse aggregates" must be avoided. It is often seen that too-dry a mix is responsible for this bad practice.

The method of maintenance of concrete road, repairing the shallow depressions with bituminous pre-mix, as advocated by the author, are worthy of note. For a renewal coat of 2 inches of cement concrete, I would recommend that it should be reinforced with two inch mesh wire netting No. 16 gauge, as specified in The Concrete Association of India's pamphlet No. 27, "BONDED CONCRETE ROADS".

In laying concrete slabs in roads, which have been widened, I would recommend that it is advisable to keep the whole sub-grade under traffic for at least one rainy season to allow the extended portion to settle and to take its final shape.

The author in para 6 (i) on page 4 (b) refers to cracks in concrete pavement laid under frosty and cold atmospheric conditions. I had an experience where freshly laid concrete road slab developed some surface

cracks when it was summer and hot wind was blowing. In this case the surface was not protected against the sun and the hot wind. Such cracks did not appear when the surface was protected by canvas soon after finishing.

I have had no experience of using hessian cloth as a cleavage plane between the old and new concrete, but would like to know of the result.

Mr. W. F. Walker (Author of Paper A—39):—I will endeavour to answer the many questions which have been asked. If I omit to do so, perhaps the questioner will mention his point later. As far as possible, I will answer questions in the order in which they were asked.

First, the question of the use of bonded brick work for roads was raised. A short experimental length was laid in Lucknow. It has been reasonably satisfactory, but it is not proposed to do any more of this work, because it is little if any cheaper than our ordinary thin cement concrete road, and it is not likely to wear as well.

The use of weak concrete for the lower portion of a concrete road and a richer mix for the top wearing coat is not an unusual type of construction. Personally, I do not like it, because it adds to the difficulties of construction, and there is always the chance of the weak mix getting to the surface, with perhaps disastrous results. With 3-inch slabs, I consider that it would be definitely dangerous to use two mixtures of concrete, and the small saving in cost would not be worth the risk.

Before we adopted the uniform thickness of slab as our new standard, we tried numerous uniform slabs alongside our previous standard slabs with thickened edges. Regular reports were made on the behaviour of these slabs. In every case it was found that there was no difference between the slabs with thickened or unthickened edges. The thickening costs money, and makes it difficult to obtain a uniform sub-grade; therefore we have dropped the thickened edges and adopted slabs of uniform thickness.

The question of the thickness of slab necessary for particular traffic was raised. In my paper I have stated that if traffic on a 12-foot wide road is less than 1000 tons per 24 hours, then 3 inches thick concrete will normally suffice; for traffic between 1000 and 2000 tons the concrete should be 4 inches thick, and for heavier traffic it should be 6 inches thick or more. I think the concrete for trackways without a good foundation should be 4½ inches to 6 inches thick. Generally, it would be cheaper to provide a good foundation of, say, 4 inches to 6 inches overburnt brick, *kankar*, stone or weak concrete, and to lay a 3-inch concrete track over this foundation, rather than put in a thicker cement concrete track. Each case would have to be decided on its merits.

My own personal opinion based on the experience we have gained in the United Provinces by constructing about 80 miles of insulated concrete road and about 30 miles of bonded concrete, road is that an insulation layer of sand is not necessary, and that better results are obtained by bonding the concrete to the road. Mr. Kynnersley yesterday expressed the opinion that paper laid under the concrete would ensure that water from the concrete was not lost in the sub-grade. When the sub-grade is merely earth, the absorption of water from the concrete may be a serious matter; but when the sub-grade

is a good solid foundation consisting of an almost impervious layer of stone or *kankar* which has been watered previously then I do not think the loss by absorption will be serious. In any case, the concrete will set within a short time and will be kept damp during curing.

Mr. Kynnersley also suggested that the paper would supply a smooth surface for the concrete to slide over, but I think the paper, not being a rigid plate, will conform to the inequalities of the sub-grade, as our friend Mr. Durrani explained. Though the bond with the sub-grade may be destroyed, yet the underside of the concrete slab laid over the paper will be rough and indented like the surface of the sub-grade itself so that the slab will not slide easily over the sub-grade. Thus, I think paper detracts from the additional strength which should result from the bond of the concrete with the sub-grade and does not really facilitate sliding of the slab under the forces due to expansion.

One other thing in this connection. If the concrete is bonded to the sub-grade, then the edges of the slabs are less likely to curl up due to the effect of the sun on the surface of the slab. The slabs also are less likely to rise up at the joints with the cantilever effect mentioned by Mr. Kynnersley, because in both these cases the sub-grade tends to hold the slab down in position. Incidentally, bonded concrete for this reason does not need dowels.

Latterly we have not used insulation, and we have practically never used dowels, Our results are good, and therefore, I argue that insulation and dowels are not necessary.

We have made our slabs of many different lengths, going up to 150 feet without joint of any kind and have come to the conclusion that slabs should be 33 feet long. This length is definitely specified and cannot be departed from in the United Provinces without special approval of the Superintending Engineer. My own personal opinion is that slabs *might* be made 50 feet long, thus reducing the number of joints by one-third. I am constructing two lengths of road with 50-foot joints at the present time, but do not advocate its general adoption until it is definitely proved to be successful by actual experience. Expansion joints 1/4 inch thick in one case and 3/8 inch thick in another are being left between each slab.

All the miles which we have made of 3 inches thickness downwards have proved successful, and practically no wear has been observed. The traffic on these thin slabs has been up to 1,000 tons per day on a 12-foot width. Even the 2-inch slabs have stood up to this. Most of the 2-inch slabs were reinforced with wire netting, etc., but it was found better and just as cheap to provide 3-inch plain concrete slabs and this is now standard in the United Provinces.

In the statements showing costs, on page 12 (a) of my paper, the cost of mixing is included in the item "Laying Concrete."

In most cases we have laid our concrete roads without a central longitudinal joint. Theoretically, I think that if the outside edges of the slabs are thickened, then the edges at the joints both lateral and longitudinal should also be thickened. In practice, this is almost

impossible. Therefore, we have not done it, and the many miles of completed road prove that thickening of these edges is not necessary.

In my opinion, all concrete roads—in India, at any rate—should be bonded to the sub-grade. whether the concrete is thick or thin. I must point out that this is only a personal opinion—the United Provinces specification stipulates that slabs 3 inches and under *must* be bonded, whilst thicker slabs *may* be bonded.

As mentioned by one speaker, dowels would not have prevented the few 'bursts' which have occurred near Ghaziabad even if these dowels had been, 10 feet long. Personally I think dowels would have made matters worse, and, in any case, 3-inch slabs hardly allow for the insertion of adequate dowels. Adequate expansion joints are necessary to prevent such 'bursts'. With ranges of temperature of 100 degrees Fahrenheit and more, expansion joints are far more necessary in India than in more temperate climates where, I think I am correct in stating, expansion joints are always provided

A suggestion was made that 3 inches stone metal might be laid over an old road and might be grouted with cement to form a good foundation. On this the 3 inches wearing surface might be laid and a good bond ensured. This, I think, would be advantageous—it is the old idea of weak concrete below a strong concrete wearing surface. The great objection to this is the expense of the grouting which would generally rule out this method of construction.

We have laid concrete on roads which have been scarified and reconsolidated. Provided that the sub-grade has been made uniform, the results have been satisfactory. On page 14 (a), our specification for the sub-grade is given. Concrete is laid immediately after the sub-grade has been completed as per this specification, which allows for reconsolidation. It is, of course, certain that the firmer the foundation, the better will be the results with the concrete.

Various people put questions with regard to the cost of maintenance, which I gave as Rs. 5 per mile. This figure refers to a few special miles and not to the general cost of maintenance; which, for about a hundred miles, is between Rs. 30 and Rs. 50 per mile.

Another question was asked about mixing lime with concrete. Our 1927 specification laid down that 1½ pounds of lime should be mixed with each bag of cement, the idea being that it would make the concrete smoother and improve its workability. Actually, for the last five years we have abandoned that and no lime is now mixed with the concrete.

Another question was about our programme. To begin with, we chose to lay concrete on a few miles of road carrying heavy traffic. This reduced the cost of maintenance. When the cost of construction came down from Rs. 45,000 to Rs. 15,000 per mile, we took up other routes less heavily trafficked. The cost of construction may be further reduced to Rs 12,000 by making the concrete 9 feet instead of 12 feet in width. The edges of the concrete would be protected on each side by strips of water-bound metal 1½ feet wide This would enable traffic to pass in safety by using the *patris*.

Various questions have been raised about the foundation. I entirely agree that the thin slabs can only be successful when the foundation is ample. It is hopeless to think of a thin concrete surface unless one has a thoroughly good foundation, and, if we have been successful in the United Provinces, it is entirely because we have laid our slabs on roads which have got a very good foundation.

There was criticism about cracking, and the suggestion was that cracks had made a failure of concrete roads. After more than 20 years' experience with cement concrete in the United Provinces, I may point out to the Congress that it has been found necessary to renew only 1 furlong out of 120 miles of cement concrete. During the same period we have renewed hundreds of miles of bituminous and tar-surfaced roads, whilst we have renewed many thousands of miles of water-bound road. When finances permit, the advantage lies overwhemingly with cement concrete, and nowadays thin slabs have reduced the capital costs to a reasonable figure.

One speaker said that he was not convinced that cracks are attributable to the insulating layer. If any one who is doubtful can find the time, I would suggest that he should go to Ghaziabad and inspect the 3½-inch thick slabs which are insulated. He will find numerous cracks. Then he should go to Cawnpore and see the 3-inch bonded slabs, or, better still, the 2-inch bonded slabs under heavier traffic than those at Ghaziabad and constructed about the same time. He can then decide for himself whether it is better to bond the concrete to the sub-grade or not.

I might say that until about 2 years ago I was a strong opponent of thin cement concrete roads. I feared that there might be serious failures. For the last 18 months I have had many miles of these thin slabs under my charge and I have been forced to change my views. The thin concrete road has proved itself to be a success under suitable conditions. This does not mean that thin concrete can be used everywhere—undoubtedly, it would fail under the heaviest city traffic, and in such cases thick concrete would be absolutely necessary.

Mr. P. V. Chance (Chairman) :—Our thanks are due to Mr. Walker and to Rai Bahadur Mukerjee for their two very valuable papers. The results of what has been done in the United Provinces will be of great assistance to any one constructing concrete roads. These two papers are among the best that we have had, and I congratulate the authors upon them.

Rai Bahadur Mukerjee who has been unable to be present, will reply to the comments on his paper by "Correspondence."

CORRESPONDENCE

Comments on Paper B-39 by S. Narayanaswami Iyer, (Vellore)

I would like to offer a few remarks on the question of development of cracks, in cement concrete wearing surfaces of roads. The author of paper B-39 has dealt with the subject at full length on page 3 (*b*), and has enumerated all the possible causes that give rise to these. He has also discussed the various methods of repairing them. On page 7 (*b*),

he states that after grouting the cracks with cement concrete, keeping the surface slightly higher than the adjoining portions, it should be left for about 40 minutes and then tamped. Again it should be allowed to set for another 30 minutes at the end of which period, he suggests the concrete grout should be tamped. On the whole, the author allows a period of 1 hour and 10 minutes to elapse before the final tamping of the cement concrete grout is completed. May I request the author to enlighten me whether there would be any effect in tamping the concrete at the end of this long period after laying and whether it is desirable at all, in view of the fact that the concrete would have completed the initial set by that time.

I would here like to give a bit of my experience in this matter. In the "Rajendra Bridge" across the Ponnai river in the North Arcot district, a bridge of 12 spans of 120 feet each, which was recently completed and opened to traffic by the Hon'ble Premier of Madras, the deck slab was completed simultaneously along with the wearing coat of concrete, the latter being 3 inches in average thickness. About 5 months after completion, slight cracks were observed in about half the number of bays, each of 42 feet 3 inches in length in the first eight spans. They were cut open and examined and it was found that the cracks did not extend below a depth of 1 inch to $1\frac{3}{4}$ inches in the wearing coat and the deck slab was perfectly in good condition. These were filled up with cement concrete of $1 : 1\frac{1}{2} : 3$, the same proportion as that of the wearing coat. But after some days the cracks began to appear in the very same places, proving thereby that this method of grouting was ineffective. I then had these portions cut out again along the lines of these cracks for a width of 3-inches and to their full depth and after inserting a piece of B. B. lathing, they were filled up with cement concrete tamped and flushed. The surface has been standing quite well now under the heavy traffic and there are no more cracks. It seems to me that some sort of reinforcement in the wearing coat or the mere insertion of tell-tale rods would avert the development of these temperature cracks. The original proposal to provide tell-tale rods between the deck slab and the wearing coat was not given effect to and in its stead "jute scrim" or Hessian fabric was introduced, before laying the wearing coat. With this dividing medium, the structure could not be thoroughly monolithic and the cleavage plane between the bottom slab and the top wearing coat was very pronounced and a hollow sound was always heard in places when tapped with a hammer. I would request the author to give his opinion, if the tell-tale rods should not be preferred to the Hessian fabric, as a dividing medium between the slab and the wearing coat.

Reply to the comments on his Paper by Rai Bahadur A. C. Mukerjee (Author of Paper B-39).

I shall take up and try to reply as far as possible to the points brought out in the comments on my paper.

I thank Mr. Das Gupta for his suggestions for Asphalt joint filling and for the formula for the mastic for repairs. Several grades and types of bitumen have been tried by me, besides prepared jointing material, and I refrained purposely to make a mention of these as I have not yet come across any, which was entirely satisfactory and could be recommended with confidence. I shall try Mr. Das Gupta's recommendations It should, however, be realised that climatic and traffic conditions in

the United provinces differ greatly from those in Bengal and I do not know if Mr. Das Gupta has kept this in view in his recommendations.

I am afraid I am unable to entertain seriously Mr. Das Gupta's suggestion of driving piles 6 feet to 10 feet long at intervals of 6 inches to 1 foot, at an angle of 45 degrees and his recommendation of water proofing porous soil with emulsion for a distance of 6 inches to 8 inches. I hope that he has driven a pile inclined at 45 degrees under an old road bed and that he realises that a water-proofed edge 6-inches to 8 inches will not prevent water-logging under the road.

Mr. Jagdish Prasad's comment is, according to the views about cement concrete, accepted as correct until recent years. There is no interference in setting with disasterous result to concrete in the tamping recommended, as initial setting time of most of the Indian cements is well above an hour and besides my personal experience and that in other countries also show that delayed tamping does not result in a weak concrete. It is not necessary to use a sloppy mix for the work. I agree with him that the mix should be dry, but it is with the qualification that it must be workable. Painting of patches is sometimes done instead of wet curing.

With regard to Mr. A. Lakshminarayana Rao's queries, I have to say that personally I do not regard 12 feet width of concrete road as at all suitable for the present day traffic, they should be 18 feet wide for two lanes of traffic. I agree that if cracks are wide enough to cause enough percolation of water, they are not harmless. In our concrete roads we do not leave any crack untreated after it has been noticed. Cracks are bound to develop where the circumstances favour them, and there is no reason yet to think that they would menace seriously the adoption of cement concrete pavements for roads.

The general principles and specifications for repairs have been written from personal experience of repairs of concrete roads in different parts of the United Provinces. I have purposely not given any figures as mentioned by Mr. Mahabir Prasad while introducing the paper.

Nawab Ahsan Yar Jung Bahadur has stressed the need for cooling of concrete, and thus doing away with expansion joints. I am aware of the cooling of concrete for dam work, and also of the use, of low-heat type cement, of mixing water at specified temperature, and of cooling of concrete mix to specified temperature etc. in crackless concrete for swimming baths, but as far as I am aware, even in America, cooled concrete has not so far been used for road pavements, which are subject to high surface temperatures as the roads in these provinces.

It will be very useful if Nawab Bahadur kindly gave details of the spacing of the construction joints, the thickness of slabs, whether they are bonded or not to the sub-grades, range of temperatures, and behaviour of the slabs and the joints etc. I agree with him that 2 inches or 3 inches deep patches make a good job and I have found that it is enough to get the edges vertical for 1½-inches from the surface.

I thank Rai Sahib Hari Chand for his kind remarks and supplementing my observations with matter from his experience. I agree that utility cuts should be eliminated with fore-sight but in actual practice cases of such cuts do crop up sometimes and mention was, therefore, made of these.

I agree that while approaching the joint, concrete for about a length of 2 feet should be laid backward from it to ensure evenness at the joint.

I agree that there should be a joint at the junction of slopes, and also that surface of concrete must be protected immediately after finishing, from sun and hot winds to prevent surface cracks.

I have read with interest Mr. S. Narayanaswami Iyer's experience of the cracks in certain bays of the concrete wearing course slab of the "Rajendra Bridge." I shall be obliged if he could kindly let me have details about the position and direction of these cracks and also the position of joints on the deck slab.

Comments on Paper A-39 by Mr. Jagmohandas T. Mehta (Bhavnagar).

In Mr. Walker's paper on "The evolution the Thin Concrete Road, in the United Provinces," it has been suggested that the edges should not be thickened as it is impossible to compact an uneven sub-grade, but, in this case I think that the stresses at the corner would be so great as to cause frequent corner breaks. If difficulty is found in compacting the uneven subgrade, reinforcement should be put for about 3 feet from the edge.

The author's point that there should be no insulation layer is perfectly correct and can not be overstressed. Sand at the bottom of the concrete, expands when it becomes wet and shrinks when it gets dried, thus the subgrade will not provide the support which is so necessary for thin roads. Hence I completely agree with the author that thin slabs should be perfectly bonded on to the subgrade.

Reply to the above comments by Mr. W. F. Walker (Author).

Mr. Mehta has suggested that there will be frequent corner breaks unless the edges of the thin concrete roads are thickened. In actual practice this has not proved to be the case. It is probable that corner breaks are due to the wheels of fast moving heavy traffic striking the corners as the vehicle moves from the *patri* to the concrete after passing another vehicle. It is my experience that the best way of preventing this damage is to provide a strip of metalling 1½ feet wide alongside the concrete. When this strip of metalling is provided then the width of the concrete could be reduced, thereby reducing the cost of the road by about 20 per cent. and also protecting the edges of the concrete from damage.

Comments on Paper B-39 by Mr. S. A. Amir (Bihar).

On page 6 (*b*), para 11 (III), it is said that 'joints and fine or shallow cracks and shallow depressions are to be filled or treated with bituminous material'. I understand from this that painting, at least in case of

shallow depressions, and then blinding with course sand or chips $\frac{1}{8}$ inch to $\frac{3}{8}$ inch according to the depth of the depressions is meant In actual practice, does such a bituminous coat stick and stay on the hard unyielding concrete base. I have seen that a full width seal with hot bitumen and $\frac{1}{2}$ inch chips on a worn cement grout macadam surface did not stick and became patchy and uneven in a short time.

On page 7 (b), para 11 (V), the method of repairing depression exceeding 1 inch in depth with cement concrete is given. If the directions were to be strictly followed it will take at least $1\frac{1}{2}$ hours from the time of giving the rapid hardening cement wash till completing the final tamping Would not this disturb the initial set and thereby give a weaker concrete. The rapid hardening cement tack coat for joining the old and new concrete should certainly suffer. If $\frac{1}{4}$ inch to $\frac{1}{2}$ inch bitumen coats in repairs to shallow depressions are to be tolerated and will stand against traffic, why cannot the depressions and patches exceeding 1-inch in depth be filled up with bituminous premixed chips ?

In para 11 (VI), on page 7 (b), a 2-inch renewal coat of cement concrete is recommended. Such a treatment could not be adopted on any important bridge road-way, as in course of a few such treatments, the dead load will appreciably increase and may cause trouble. What should be the alternative method of repair in this case ?

Reply to the above comments by Rai Bahadur A. C. Mukerjee (Author).

The bitumen coat does stick all right, but cannot stand traffic for long and gives way and has to be renewed. This is not an ideal treatment, but one that can be easily adopted practically and has been used a good deal.

The initial setting time of several Indian cements used by the writer has been in the neighbourhood of two hours and such cement could be easily used. Bituminous premix has been actually used in repairing patches and the results have not been satisfactory. It is easier and less expensive to repair a painted surface than a premix surface, and when a good job can be made with concrete in deep patches it is obviously not necessary to take to repairs with a bituminous premix.

The renewal treatments can be needed only at very long intervals. Still if in any particular case the increase in the dead load is to be guarded against, one method to employ would be to spread a layer of cement mortar over the surface, cover it with damp hessian cloth 1/8 inch mesh and then lay the cement concrete, tamp and finish in the usual manner. When this coat is worn out, it can be easily removed in fairly large chunks with chisels, due to the cleavage fabric (*i.e.*, the hessian cloth) introduced.

Before laying the next coat, a layer of damp hessian cloth is again spread and concrete laid.

PAPER D—39.

Rai Bahadur S. N. Bhaduri (Chairman) :—I call upon Dr. M. A. Korni to introduce his Paper "Sai Bridge".

The following Paper was then taken as read :—

PAPER No. D—39

THE SAI BRIDGE

(JAUNPORE, UNITED PROVINCES)

BY

DR. M. A. KORNI, M.I.E. (IND.).

General Description :— The bridge is built on masonry piers and abutments. The main girders are spaced 7 feet 10 inches apart, centre to centre, and carry a clear width of 20 feet roadway. The piers are built over two masonry wells each, and the abutments and wings over four wells each. The beams, bed-blocks, deck-slab and keıb-stones are of reinforced concrete, and the wearing surface of the roadway is of plain cement concrete 2 inches thick. The handrails are of mild steel angle Iron uprights and galvanized pipe rails 1½ inches external diametre. The bridge is designed for traffic of all kinds, both pedestrian and vehicular, equal to a live-load consisting of 15 tons (gross 16½ tons, when in working order) road roller preceded and followed by a crowd of 20 men assumed to weigh 84 pounds per square foot. The proportion of concrete in various members of the bridge is designed according to the Public Works Department Specification so as to develop a specified crushing strength in each member after 28 days of setting, as noted below :—

Reinforced Concrete Well Curb. Reinforced Concrete Long Beams. Reinforced Concrete Cross Beams. Reinforced Concrete Deck Slab. Reinforced Concrete Kerb Stone.	3,000 pounds per square inch.
Reinforced Concrete Slab on top of the piers.	1,200 pounds per square inch.
Plain Concrete, 2 inches thick in the wearing surface of roadway.	4,000 pounds per square inch.

The quantities or work, which may be of interest to Bridge Designers and Bridge Builders, are as follows :—

Excavation, in foundation soil.	99,405 cubic feet.
Side-Filling of Trenches,	66,270 cubic feet.
Reinforced Concrete Well Curb.	16 numbers.
Brick-in-lime, in steining of wells, with 1 lime, ½ sand and 1½ soorki.	35,829 cubic feet.
Steel work, in bond rods and bond plates.	178 hundredweights.
Sinking Wells,	480 running feet.

Cement Concrete 1 : 3 : 6, in bottom plugging of wells, 3 feet deep, with jhama chips and local river sand.	3,404 cubic feet.
Local river sand filling, in wells.	15,400 cubic feet.
Cement concrete 1 : 3 : 6, in top plugging of wells, 2 feet deep, with jhama chips and local sand.	1,232 cubic feet.
Cement concrete with jhama chips and local river sand, in capping slab over wells, including reinforcement.	6,431 cubic feet.
Brick-in-lime in piers, abutments and wings.	39,865 cubic feet.
Cement pointing 1 : 3. in piers, abutments and wings.	9,635 square feet.
String Course and Moulding, in piers.	230 running feet.
Cement Concrete 1 : 3 : 6, with jhama chips and local river sand, in caps of cut-water.	320 cubic feet.
Flush Cement pointing, in outside of wells.	18,103 square feet.
Cement Concrete, in long beams, including reinforcement.	7,976 cubic feet.
Cement Concrete, in cross beams.	640 cubic feet.
Cement Concrete, in deck slab, including reinforcement.	4,246 cubic feet.
Cement Concrete, in Kerb Stone.	519 cubic feet.
Cement Concrete, in bed block of beams over piers and abutments.	520 cubic feet.
1 inch internal diameter Galvanized Iron Pipe Railing	2,316 running feet.
Steel work, in uprights, including fitting and fixing.	25 hundredweights.
Cement washing, in all exposed Reinforced Concrete work.	34,855 square feet.
Expansion Joint.	88 running feet.
2 inches thick, Cement Concrete Roadway.	7,720 square feet.

* The total cost is Rs. 1,47,678 -.

* Cost of foundations including piers and abutments.	Rs. 68,000
Cost of Superstructure.	Rs. 79,678
Cost per square foot area of foundations.	Rs 9.2
Cost per square foot area of Superstructure.	Rs 10.76

Hydraulic Characteristics of the Vicinity (see plate 1.) :—The site of the bridge is situated in a catchment area of 4,272 square miles with a maximum discharge of 1,81,810 cubic feet per second. The average velocity observed during the highest flood level on September 23 in 1935 was found to be 4.8 feet per second. The deepest scour-holes were found about 6 furlongs upstream of the bridge site.

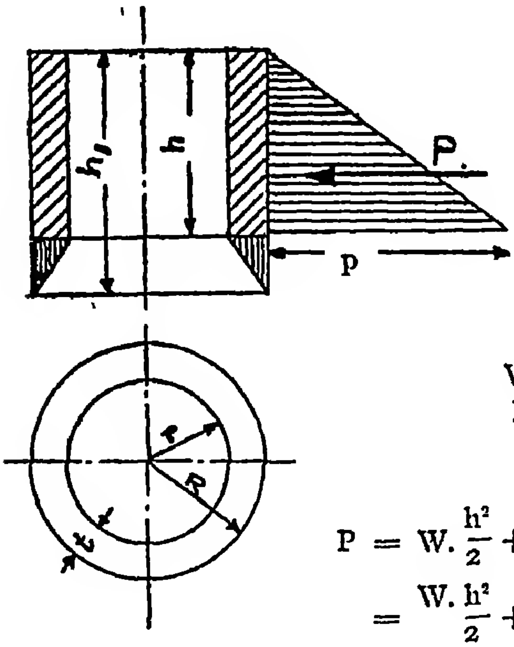
The Working Months :—In October 1936, the flood level of the Sai river at Jaunpur exceeded the previous high flood level by 1.11 feet and due to this the design had to be revised and the piers and abutments increased in height by 2 feet, but the decision was afterwards cancelled on October 13, 1936. The monsoon in this vicinity breaks out about the middle of June and the river gets fully flooded from the middle of June to the end of September. Between this period sinking of wells is impossible, but the erection of abutments and wing-walls, (in view of the rainfall in the beginning of the monsoon not being high), was started but it was necessary to take precautions against land sliding on the Mirzapur side.

Geloogical Formation :—The Geological formation of the river bed, particularly under the bridge, was carefully observed. It is the characteristic of the district that the river beds are of the same formation as we find that the bed of the Ganges river near Benares is practically formed of the same strata. The first stratum consists of fine silt; underneath it is a stratum of (see plate 2) yellow hard clay and still deeper is a stratum of clay and kankar. It can be seen from the cross-section of the river that the banks consist of strata of kankar of a considerable thickness, and towards the middle of the river this strata is thinned out. This indicates that a violent deterioration of the kankar strata had taken place, notwithstanding the fact that the bearing capacity of kankar is very great. Therefore, it was decided that the wells should be sunk sufficiently deep and the bridge should be of the cantilever type, as it was found that the piers may, with the time, act like elastic props which in case of continuous beam design may produce detrimental stresses in the bridge.

Erection of Abutments and Wells :—The erection of the abutments was started long before the monsoon. They were placed on 4 wells which were sunk to reduced level 50.5. The sinking of the wells of these abutments was quite an easy job in comparison with the sinking of wells under the piers.

Type of Wells :—Under each pier two circular wells were sunk to reduced level 38.00. The writer has experience in sinking wells of various shapes in India and made the Public Works Department of the United Provinces to agree to these wells in preference to the other shapes of wells for reasons of economy, and other reasons as well. The principal reason for preference to any rectangular or long shaped wells is that, circular brick wells are more uniformly stressed being always under compression (which is the appropriate stress for the material and its mortar). The calculation of a circular well is also very simple. If the inner radius of the well is chosen and assuming that the bricks and mortar can take up a compressive

stress of 6 tons per square foot, the outer radius of the well is easily defined by the formula :—



$$R = r.\sqrt{\frac{6\ \text{tons}}{6\ \text{tons}-0.09\ p}}$$

Whereas $p = \frac{5}{4}h$ as proved below.

In denoting P = the total active pressure in tons.

θ = angle of repose = 36 degrees (in general)

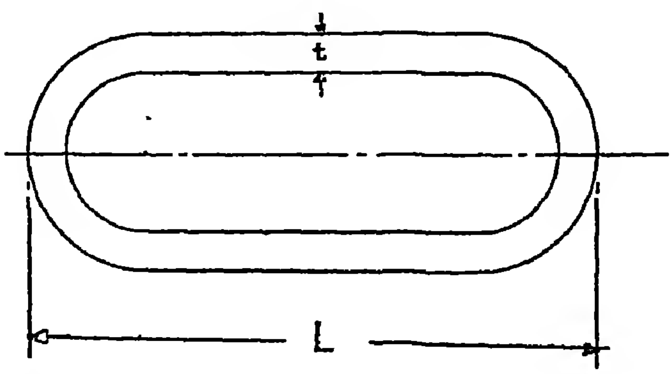
$\frac{W}{E}$ = Ratio of weight of 1 cubic foot $\frac{\text{water}}{\text{earth}} = \frac{62.5}{125} = \frac{1}{2}$

$$P = W.\frac{h^2}{2} + \left(\frac{E-W}{2}\right).\ h^2 \times \tan^2\left(45^\circ - \frac{\theta}{2}\right)$$

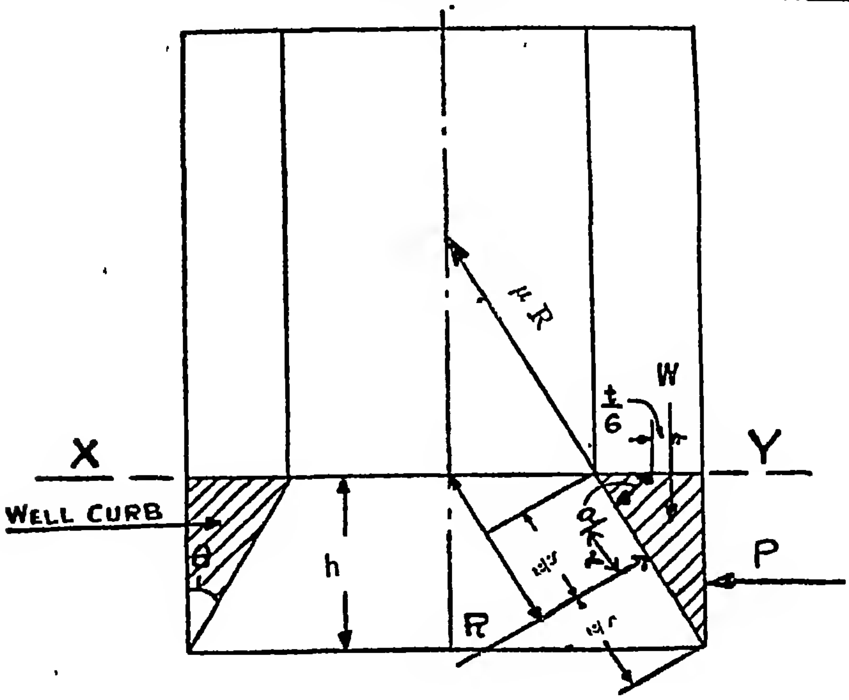
$$= W.\frac{h^2}{2} + \left(\frac{E-W}{2}\right).\ h^2 \times \tan^2 27^\circ = \frac{5}{8}h^2 = \frac{ph}{2}$$

and therefore, $p = \frac{5}{4}h$

In rectangular or long shaped wells, due to earth pressure P, a bending moment causing tensile stresses in brick and in the joints may always bring about a rupture in the wells at the time of sinking. The bending moment in such wells is $\frac{5}{48}hL^2$. This will cause an equivalent tensile stress $f_t = \frac{5}{8}\frac{hL^2}{t}$ whereas "t" denotes the thickness of the steining of the well near the curb. There are many other practical reasons why a circular well should be preferred, as for example, easier excavation around the well curb, etc.



Reinforced Concrete Well Curbs :—The well curbs are of reinforced concrete. The dimensions as shown in the drawing are based on the principle that the effect of total strains in the kerb produced by a variable bending moment along the axis x-y must be zero



If we denote Bm = Bending Moment

W = Weight

μ = Co-efficient of Friction

R = Resultant of the Reactions.

The maximum Bending Moment in X—Y can be found from the following equation of mon ent:—

$$Bm = W.\frac{t}{6} - R.r + \mu.R.a \text{ ....} (I).$$

$$\text{but } r = \frac{h}{\operatorname{Cos}\theta} - \frac{t}{2}\operatorname{Sin}\theta - \frac{S}{2}, \text{ and } a = \frac{t}{2}\operatorname{Cos}\theta$$

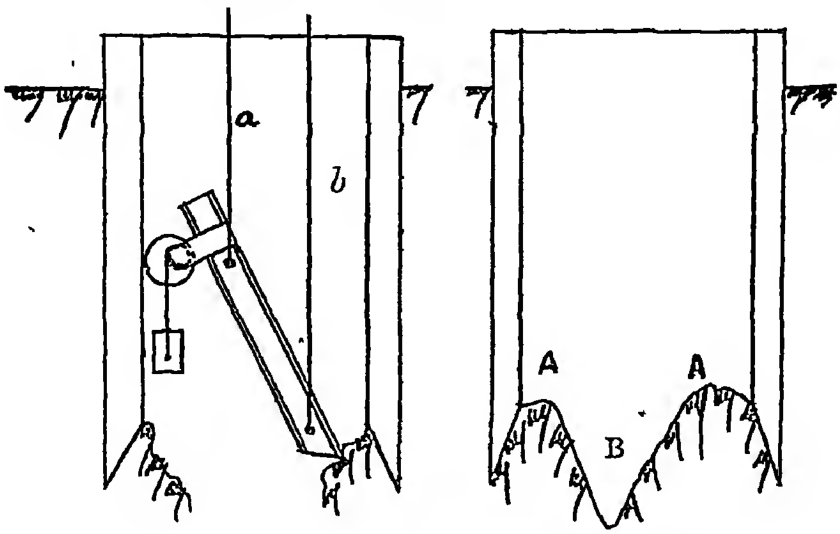
Substituting these values in formula (I) above, we get :—

$$Bm = W\frac{t}{6} - R\left(\frac{h}{\operatorname{Cos}\theta} - \frac{t}{2}\operatorname{Sin}\theta. - \frac{S}{2} - \mu\frac{t}{2}\operatorname{Cos}\theta\right) \text{....} (II).$$

The practice in India is to place the wells on built up islands in the river as the river after the monsoon is very shallow. But, often, to release the skin friction of the wells in order to facilitate the sinking, water jetting around the wells is done. Therefore, the horizontal pressure has been neglected in the equations I and II.

Well Sinking :—The sinking of wells for the piers was met with difficulties due to the Geological conditions of the river bed already described (see plate 2). The estimate ,of this contract provided for the simple method of sinking as usually adopted in this country, namely, hand dredging inside the well, sand filled bags in place of kentledges to accelerate sinking, cofferdams made of mud in gunny bags and C. I. Sheets etc. were taken into consideration. But it was never realised that this simple

and cheap method will not work satisfactorily. As the digging was very poor in quantity a constant chiselling had to be done. The kankar strata was so hard that throwing of heavy chisels alone could not affect any soil-splitting. Further, it was found that the chisel, instead of piercing, slides down a narrow vertical cone 'B' in the well as shown in the sketch. Therefore, all efforts were concentrated to break the edges 'A' of the lime kankar with a specially designed chisel as shown in the sketch.

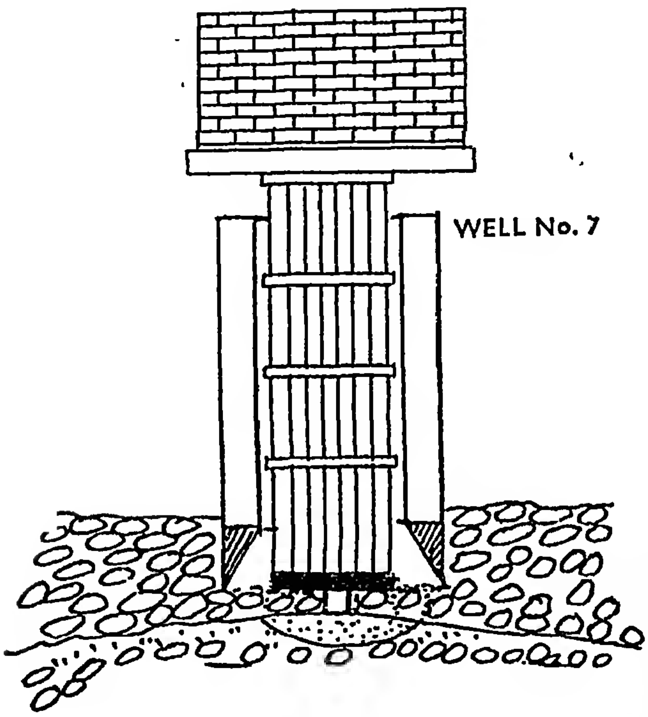


The chisel was made of rails with a knife-point on the edge.

The chisel was drawn into the well by the rope "a" and chiselled with the rope "b". Unfortunately, this kind of chisel requires exact location which could not be managed with the local workers. It was then decided to pump the well dry and to clear the space by hand chiselling. Not having electricity, in the vicinity it was out of question to instal an electric pump. Therefore, it was decided to place the pump in a digged out chamber about 12 feet deep. The chamber was water-proofed as shown in the drawing. The chamber was built of two layers of brick divided by a

layer of Sisalkraft paper. The bottom of the chamber is placed at reduced level 56 30 and the pump at the suction came to reduced level 58.00. The bottom of the curb when further sunk had to be at reduced level 38.00. Therefore the total suction head of water is 20 feet. By this method we succeeded in lowering down some wells to the required reduced level but several others were unmanageable, due to water blowing into them. For these wells, it was decided (as no other means were left) to bring a diver

who was working at Scindhia Ghat construction at Benares at that time. By means of blasting and manual cleaning of the debris, these wells were sunk to the required level. Due to these unforseen difficulties, a loss of time and money was experienced by the contractors. The wells were made of radial bricks and according to the Public Works Department Specification, bond-plates of adequate lengths were fixed in position at every 10 feet. The bond rods are cut and threaded and provided with nuts screwed tight to hold the bond plates before the sinking operation. Bottle nuts have been arranged so that they could be fixed in place of ordinary nuts and the bond rods screwed into these when the next depth of steining was built over it. The object of these bond rods and bond plates is that the steining acts as one mass during the sinking operation.



Soil Test. Before plugging the wells, it was decided to test their bearing capacity. For this purpose a base plate was lowered into the bottom of the well and a trestle, provided with a platform for taking the load, was built on it. Wells Nos. 7 and 8 were on doubtful strata and, therefore No. 7 was tested first.

On the third day of the test, after the completion of the loading when there was only 3 tons of load remaining to be removed from the trestle out of the total load of 22 tons, the trestle, all of a sudden, sank down by nearly 4 feet 6 inches.

Result of the Test. Investigations revealed that a sump was made inside the well of a considerable depth below the point on which the well curb rested and on this sump the base plate had come to be placed for carrying the test load. Originally, a boring had been made in centre of the well, and subsequent pumping, in all probability, had caused the sand of the underlying strata to be sucked up and had caused the formation of an inverted hollow cone in the strata of kankar and clay, as is illustrated in the sketch. While the test load was being removed, some jerk had possibly caused the heavy test load to punch through the intermediate thin stratum of kankar and clay. From examination of the further section, it was found that there is a strata-depth of about 7 feet of kankar and clay, below the bottom of the well kerb, and this thickness appeared to be ample to take the anticipated load. This point was further strengthened by a successful test on well No. 8 in which the well kerb had been taken nearly 9 inches deeper than in well No. 7, thus leaving a comparatively thinner layer of kankar and clay. To dispense with further sinking of well No. 7 all the debris of the broken thin layer from the hollow cone were removed and the entire cavity filled up with 1 : 2 : 4 concrete up to the level of the bottom of the well.

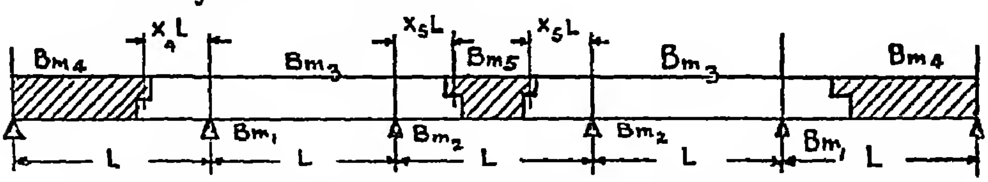
Capping.—The capping on each pair of wells is of 1 : 2 : 4 Reinforced Concrete. The length of the capping-slab is 29 feet 10½ inches and its width 9 feet 10½ inches, the thickness being 2 feet.

Piers.—The piers 29 feet in height, have a length at the bottom of 28 feet 10½ inches and at the top of 25 feet which makes a batter of 1 in 16. They are all built in brick-in-lime mortar (1 lime, 1½ sand, 1½ surki), with 1 : 3 cement pointing. There is nothing of interest to be mentioned about the brick piers except stating the reason for choosing the material, *viz.* that the bricks in the vicinity are of good quality and are cheap. On the top of the piers are placed Reinforced Concrete Bed-Blocks (12 inches thick) for the main beams of the bridge. The aggregate used in these blocks is *Jhama* chips.

Cantilever Type (see plate 3).—The bridge, as already mentioned, is of cantilever type. This type has been introduced in India by the writer of the paper in about 1933. (The first bridge of this type which was built by Messrs. Bird and Company is the Jessore Bridge in Bengal.) The Sai Bridge consists of 6 long beams, 106 feet each and 3 (central slung) beams 56 feet long and 6 end beams also 56 feet long each. The cantilever ends are 14 feet 6 inches long measured from the centre of the pier. The longest span is 85 feet centre to centre of the piers. Two spans are of 77 feet and the shore spans are of 70 feet 6 inches each. The main girders are placed 7 feet 10 inches apart, centre to centre, and carry a roadway of 20 feet width.

Gerber Bridge.—The cantilever bridge has this advantage over a bridge with continuous beams on several supports, that the system is statically determinate, makes room for expansion and contraction and is not effected when the foundation under a pier is yielding. The cantilever beam was invented by a German engineer, named Gerber, at the beginning of the 19th century and this type of bridge in Germany often goes under the name of Gerber Bridge or Gerber Beams. In the case of steel cantilever beams, the ends are interlocked with hinges. The economic sections of the cantilever beams are obtained when the maximum positive moment in the middle of the span is equalised with the maximum negative bending moment of the cantilever.

Condition for Economical Section.—



In the case of five spans bridge when the spans are all equal to L, the dead load is W pounds per square foot, and Live Load=P pounds per square foot, and Q=W+P make

$$X_4=\frac{Q}{4(Q+W)} \quad \text{and} \quad X_5=\tfrac{1}{2}-\tfrac{1}{2}\sqrt{\frac{Q}{W+Q}}$$

Then $Bm_1=Bm_2=Bm_3$

$$=\frac{QX_4L^2}{2}$$

$$Bm_4=\frac{QL^2}{8}(1-X_4)^2$$

$$Bm_5=\frac{QL^2}{8}(1-2X_5)^2$$

If only Q, the combined load, is to be taken into account, the calculations are still more simplified. That makes

$$X_1=0.125$$
$$X_3=0.1465 \text{ and}$$
$$Bm_1=Bm_2=Bm_3=0.0625\ Q\ L^2$$
$$Bm_4=0.0957\ Q\ L^2$$

Formulæ for different spans may be found in the annex. These formulæ are given in this paper to meet the demands of many engineers and students who have approached the author with the request to publish them at the next opportunity as these formulæ are not found in the English literature. In the case of the Sai Bridge, spans being of unequal lengths, it was found that the most economic section could be made if $X_3=0.143$ and $X_4=0.162$. The display of stresses due to Live and Dead Load can be better realised by studying the influence lines of the bridge, and Plates 1 to 7. The table below shows the bending moments in the beams :—

	Bm_5 in Slung Span	$Bm_1=Bm_2$ at Support	Bm_3 in Centre	Bm_4
From Dead Load	+767000 Lbs. ft.	−773000 Lbs ft.	+487000 Lbs. ft.	Change in Position 583250
Live Load	+583250 ,,	−634600 ,,	±875000 ,, ±634600 ,,	
Total	+1350250 ,,	−1407600 ,,	+1362000 ,, +1121600 ,,	

From the table it is also to be seen that the Governing Bending Moments are of nearly the same magnitude.

Cantilever Ends.—The most important parts of the beams are their cantilever ends, the failure of which would mean the failure of the whole bridge. The most dangerous section in a cantilever end is the angle of re-entrance. Such angles are causing the most unfavourable stresses, the location of which must be carefully traced and taken off by special reinforcement. The cause of the extraordinary stresses is the sudden change in the sectional area at the ends of the cantilever.

The table below gives the shears in cantilever ends :—

			Near piers.
Dead Load	..	51000	72300
Live Load	..	42900	49150
Total	..	93900 lbs.	121450 lbs.

As an example, the detailed calculation of the Sai Bridge cantilever ends is reproduced here in an elementary way and, for the sake of putting the case in a more convenient form, the graphical method of dealing with the subject has been chosen.

Articulation Section.—Graphical checking, (see plate 4).

The section and plan are shown below :—

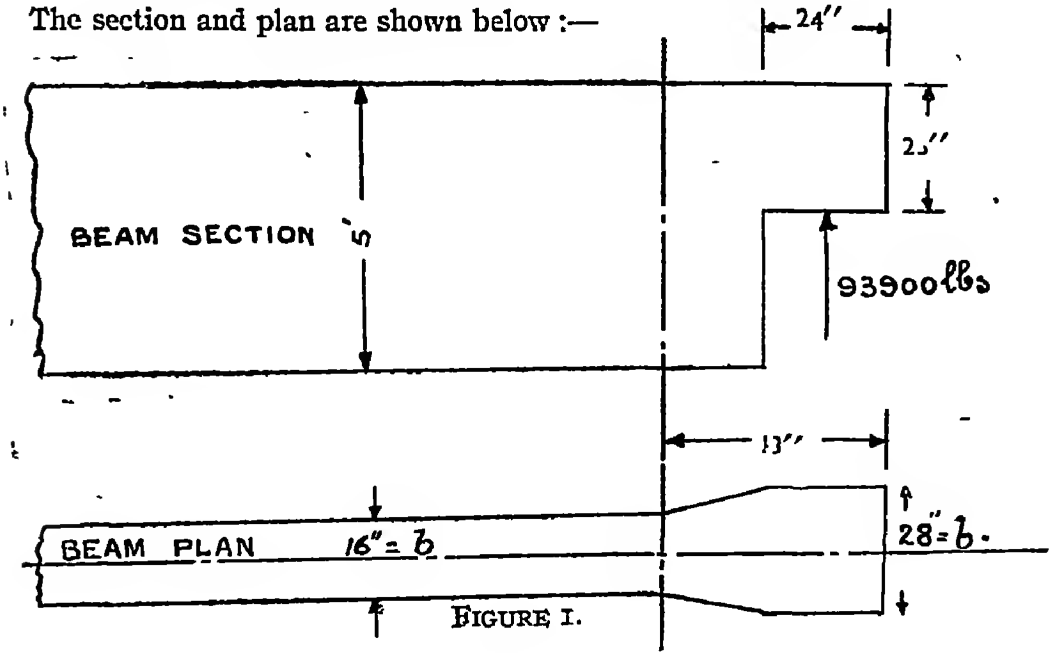


FIGURE 1.

Reaction at the end is 93,900 lbs.

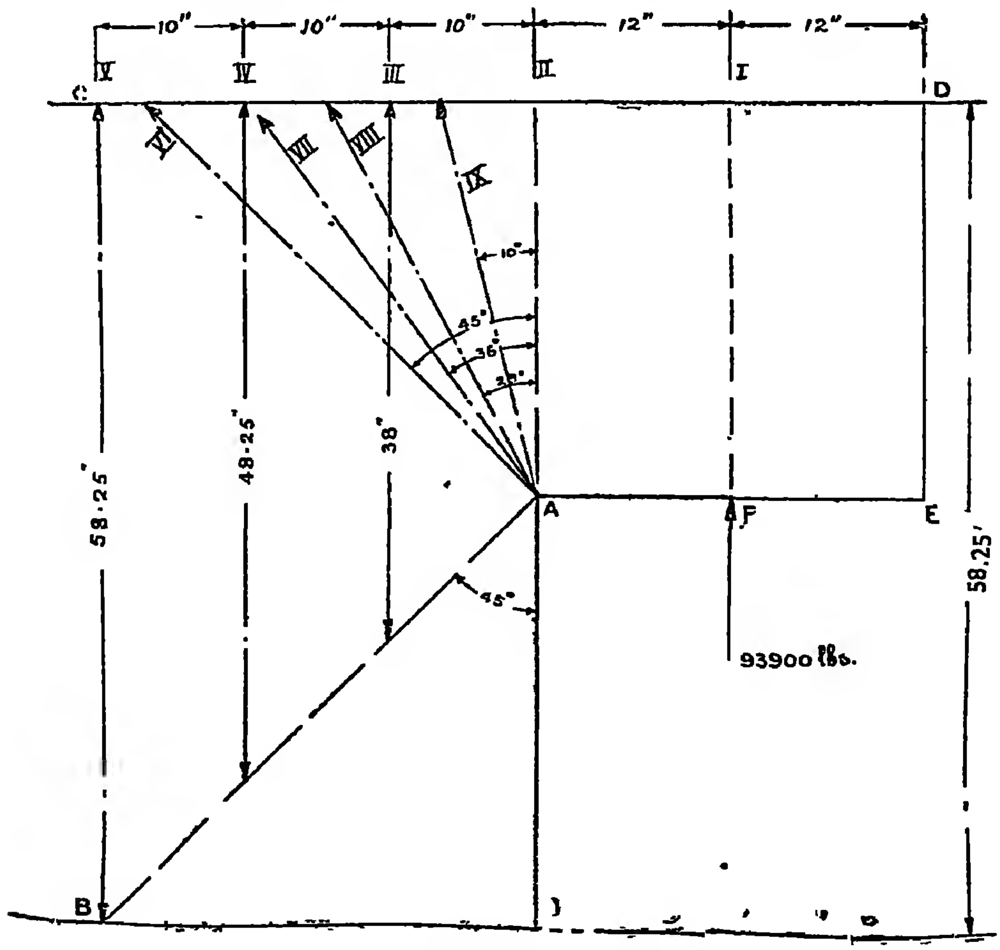


FIGURE 2.

The line AB is drawn from A (figure 2) at an angle of 45 degrees. ABCDE (figure 2) is the possible region where failure may occur due to Bending Moments and shear forces. Therefore, any nine Sections are taken in that region as shown in figure 2.

Length of Section I=28 inches
Length of Section II=28 inches
Length of Section III=38 inches
Length of Section IV=48.25 inches
Length of Section V=58.25 inches
Length of Section VI=39.75 inches
Length of Section VII=34.5 inches
Length of Section VIII=31.75 inches
Length of Section IX=28.25 inches

The Bending Moments and shear forces, etc., tabulated below are as calculated at the various Sections :—

No. of Sections	** Areas square inches A	Modulus of Section $Z=\frac{bd^2}{6}$ in.^{3}	Bending Moment Bm inch pounds.	Normal Force N. pounds.	Shear Force Q. pounds.	$\frac{N}{A}$ pounds per sqr. inch.	$\frac{Bm}{Z}$ pounds per sqr. inch
I	28×28 =784	3660	281700*	0	46950	0	77
II	784	3660	1126800	0	93900	0	308
III	38×16 =608	3850	2065800	0	93900	0	534
IV	48.25×16 =772	6200	3004800	0	93900	0	484
V	58.25×16 =932	9050	3943800	0	93900	0	436
VI	39.75×16 =636	4220	2458400	66500	66500	104.5	583
VII	34.5×16 =552	3170	2065800	55200	76000	100.0	652
VIII	31.75×16 =508	2690	1818400	45500	82100	89.5	675
IX	28.25×16 =452	2130	1325900	16300	92400	36.1	622

* The Bending Moment in Section I is due to expansion and contraction.

** To be on the safe side, the sections have been taken to be rectangular instead of trapezoidal and their width has been taken to be 16 inches.

	Compressive Stress f_c —lbs./sq. in.	Tensile Stress f_t +lbs./sq. in.	Shear Stress* $v=\frac{Q}{bjd}$ lbs./sq. in.
Section No. I	− 77	+ 77	69
Section No. II	−308	+308	138
Section No. III	−534	+534	178
Section No. IV	−484	+484	140
Section No. V	−436	+436	116
Section No. VI	−478.5	+687.5	121
Section No. VII	−552	+752	158
Section No. VIII	−585.5	+764 5	186
Section No. IX	−585.9	+658.1	234

Note 1 :—

Bending Moment in Section I=46,950×6″ =281,700 inch pounds.

Bending Moment in Section II=93,900×12″=1,126,800 inch pounds

Bending Moments in inclined Sections:—Take Section VII. Bending Moment at top of Section=93,900×32″=3,004,800 inch pounds and Bending Moment at bottom of Section at A =93,900×12″=1,126,800 inch pounds. We have taken the average Bending Moment, which is equal to $\frac{3,004,800+1,126,800}{2}$ inch pounds =2,065,800 inch pounds.

Note 2 :—

Shear Force.—On Vertical Sections, we have taken the same shear force as at F (figure 2). On inclined Sections, the shear force at Section II is resolved into two component forces, one along the inclined Section and the other perpendicular to the inclined Section. By doing this, we get the shear force along any inclined Section and also the normal force acting on that Section. The shear force in Section VI has been worked out below by this method graphically (See figure 3) :—

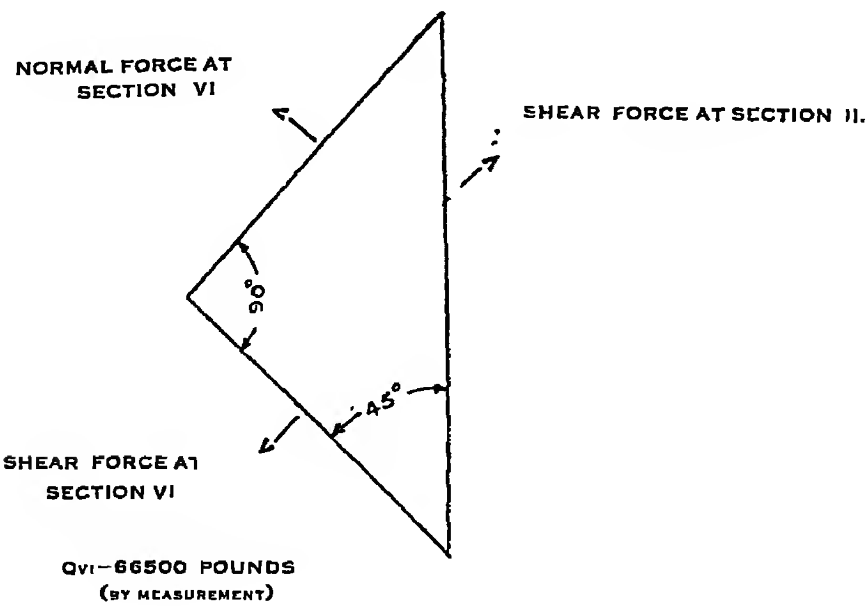


FIGURE 3

* In calculating shear stress, j is taken to be 0.87

Section VIII (See figure 5) :—Section VIII will now be investigated in greater detail as this is the worst case as seen from the table. To be on the safe side, we have taken the section to be rectangular [see fig. 4 (*a*)] instead of trapezoidal [see fig. 4 (*b*)] with b=16 inches and d=31.75 inches

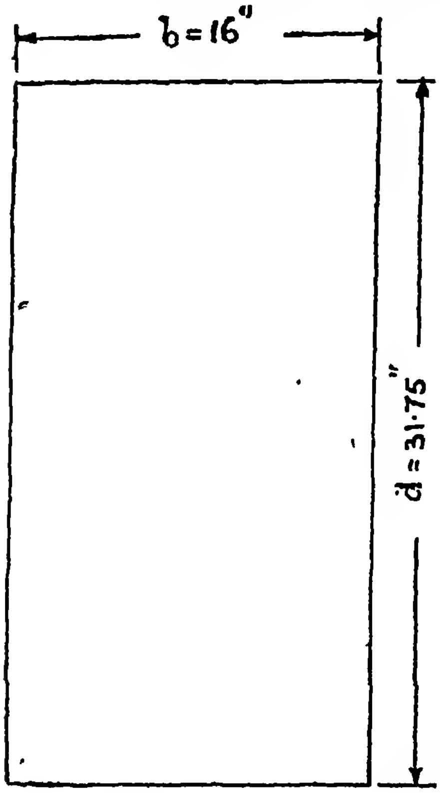


FIGURE 4 (*a*).

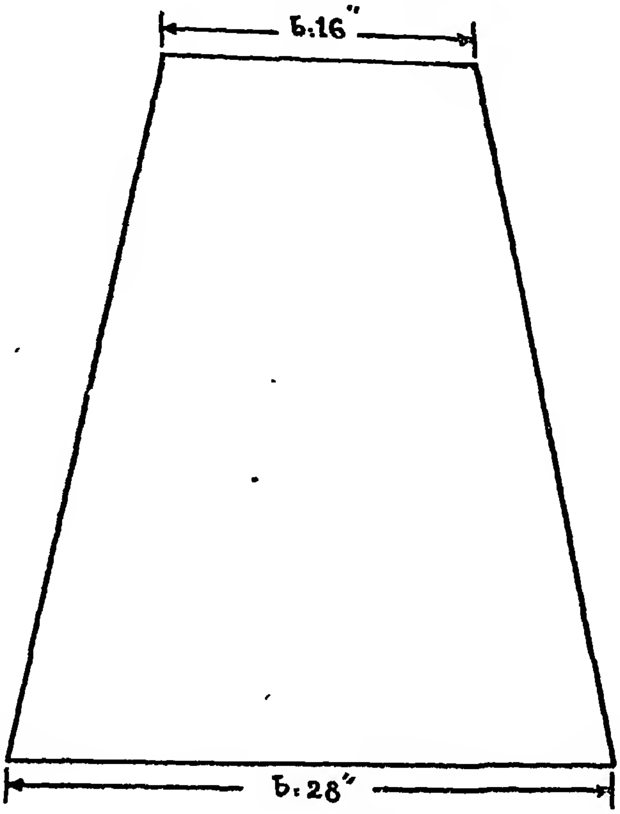


FIGURE 4 (*b*).

The section is divided into eight equal parts, and at the centroid of each rectangular strip the forces 1, 2, 3, etc., are marked. We find out the area of concrete of each strip, the equivalent area of steel and the eccentricity.

Area of concrete of each strip $\frac{16 \times 31.75}{8} = 63.50$ Square inches.

Equivalent area of steel, part I$=4 \times 1.227 \times 15 = 73.62$ Square inches.
Equivalent area of steel, part II$=2 \times 1.227 \times 15 = 36.81$ Square inches.
Equivalent area of steel, part III$=2 \times 1.227 \times 15 = 36.81$ Square inches.

$$\text{Eccentricity} = C = \left\{ \frac{\text{Bending Moment at Section VIII}}{\text{Normal force at Section VIII}} \right\}$$

$$= \frac{1,818,400}{45,500} = 39.96 \text{ inches}$$

We draw the polar diagram next. Lines ab, bc, cd, etc., are drawn parallel to the forces 1, 2, 3, etc., and equal in magnitude. Take any point O, so that H, the horizontal distance, is equal to 400. Join Oa, Ob, Oc, etc., Then Oa, Ob, etc., will represent the forces 1, 2, 3, etc., as marked in Section VIII.

Let G be the centroid of Section VIII, and GN represent the distance of eccentricity which is equal to 39.96 inches.

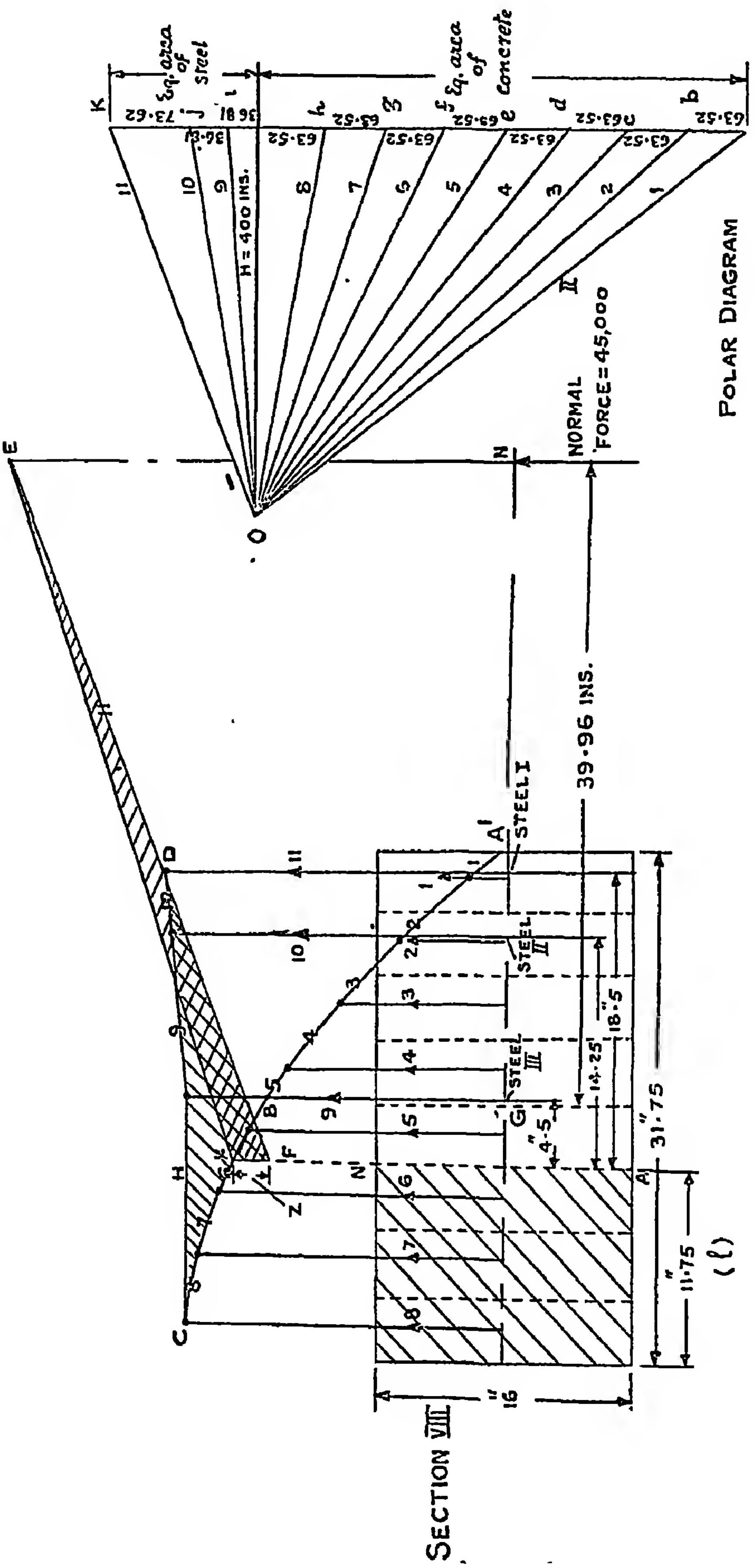

POLAR DIAGRAM
NORMAL FORCE = 45,000
H = 400 INS.
Sq. area of steel
Sq. area of concrete
39·96 INS.
STEEL I
STEEL II
STEEL III
31·75"
18·5"
14·25"
4·5"
11·75"
16"
SECTION VIII
(l)

FIGURE 5

The normal force N starts to act from section VI. We start drawing the funicular polygon from A′. The ray 1, representing Oa, is drawn parallel in direction to it, and cuts the force 1, and then ray 2 is drawn parallel to Ob from the point where the ray 1 and the force 1 have intersected. Similarly with the other rays. The last ray (11) is drawn from D and produced till it meets the normal force at E. The line ED is produced and meets the funicular polygon at B. Then we find out the area of figure BKCD. The area of triangle EKF is so adjusted by trials that this area is equal to the area of figure BKCD. By doing this, we get Z=KF=2.25 inches.

The line KF is produced, and KFNA is drawn which cuts the section VIII at N and A. This is the neutral axis of the section. The compression area is shown hatched with black ink.

$$\text{Stress in Concrete}=\frac{11.75 \times 45.500}{400 \times 2.25}=\frac{N1.}{H.Z}$$

$$=594 \text{ pounds per square inch}$$

(See Page 305, Principles of Plain and Reinforced Concrete construction by Dr. Probst).

$$\text{Tensile stress in Steel, part I}=\frac{18.5 \times 45{,}000 \times 15}{400 \times 2.25}=14{,}000 \text{ pounds per square inch.}$$

$$\text{Tensile stress in Steel, part II}=\frac{14.25 \times 45{,}000 \times 15}{400 \times 2.25}=10{,}750 \text{ pounds per square inch.}$$

$$\text{Tensile stress in Steel, part III}=\frac{4.5 \times 45{,}000 \times 15}{400 \times 2.25}=3375 \text{ pounds per square inch.}$$

The above stresses are allowable.

Section VI :—We will now investigate the stresses in this Section. It is inclined at an angle of 45 degrees. Considering horizontal bars, Morse Theory gives diagonal force in $\text{bars}=\dfrac{Q}{\cos\theta}$

$$=\frac{93900}{0.707}=1{,}33{,}000 \text{ pounds.}$$

Section area of 8 diagonal bars of $1\frac{1}{4}$ inch diameter

$=8 \times 1.227=9\ 82$ square inches.

Horizontal steel at bottom, (10 bars of $1\frac{1}{4}$ inch diameter)

$=10 \times 1.227=12.27$ square inches.

which gives at $45^0=12.27 \times \cos 45^0=12.27 \times 0.707$

$=8.67$ square inches

Total area, normal to the Section $=(9.82+8.67)$

$=18.49$ square inches.

$$\therefore \text{Stress in Steel}=\frac{1{,}33{,}000}{18.49}=7{,}200 \text{ pounds per square inch.}$$

$$\text{Total force, in horizontal bars}=\frac{1{,}33{,}000}{18.49}\times 8.67=62{,}500 \text{ pounds.}$$

$$\text{Per bar}=\frac{62{,}500}{10}=6{,}250 \text{ pounds}=2.79 \text{ tons.}$$

Resistance to Slipping.

Resistance to Slipping $= \pi dlT$.

Where d = diameter of Steel rod.

l = length of rod.

T = Co-efficient of adhesion, and is taken equal to 100 pounds per square inch

Consider the 10 horizontal rods at bottom

$$\pi dlT = \frac{3.14 \times 1.25 \times 34 \times 100}{2240} = 5.95 \text{ tons.}$$

This is more than the pull coming on the rod, which is equal to 2.79 tons only. It is, therefore, safe against slipping.

Investigation for Shear.

From the table above, we find that the maximum shear is at Section IX and is equal to 234 pounds per square inch.

$$\text{Diagonal force} = \frac{T_0+T'_x}{2} \times \frac{bh}{\sqrt{2}}$$

Where T_0 = Allowable Adhesion,

T'_x = Shear Stress,

b = Width of beam = 16 inches,

h = 24 inches in our case,

$T'_x = \frac{Q}{bjd}$ =234 pounds per square inch, which is less than four times the allowable Shear Stress (See I.R.C. Code of Practice page 89). ($4 \times 75 = 300$ pounds per square inches).

$T_0+T'_x$ = 250 pounds per square inch [We will allow this much].

$\therefore$ T_0 = 16 pounds per square inch.

$$\text{Diagonal force} = \frac{250}{2} \times \frac{16 \times 24}{\sqrt{2}}$$

$$= \frac{250 \times 16 \times 24}{2 \times 1.414} = 34{,}000 \text{ pounds.}$$

$$\text{Area required} = \frac{34000}{16000} = 2.13 \text{ square inches.}$$

We have 8 rods $1\frac{1}{4}$-inch diameter, giving 9.82 square inches.

Stiffeners or Cross beams.—It is unfortunate that many Engineers do not realise the valuable function of a Stiffener and the economy which can be obtained if the same is rightly exploited. To consider the cross beam as merely a stabilising member of a series of beams is simply waste of money, as there are cheaper means of doing so. But if considered as a member of a frame having a rigidity factor $C = \left(\frac{b}{l}\right)^{4} \cdot \frac{I}{I_1}$ reducing the Bending moments in the Main beams, the economy obtained thereby will be considerable.

To justify what has been said above, consider a system of 3 beams connected with a stiffener and let b denotes the length of the stiffener
L length of the main Beam
I moment of inertia of Beam
I_1 moment of inertia of Stiffener

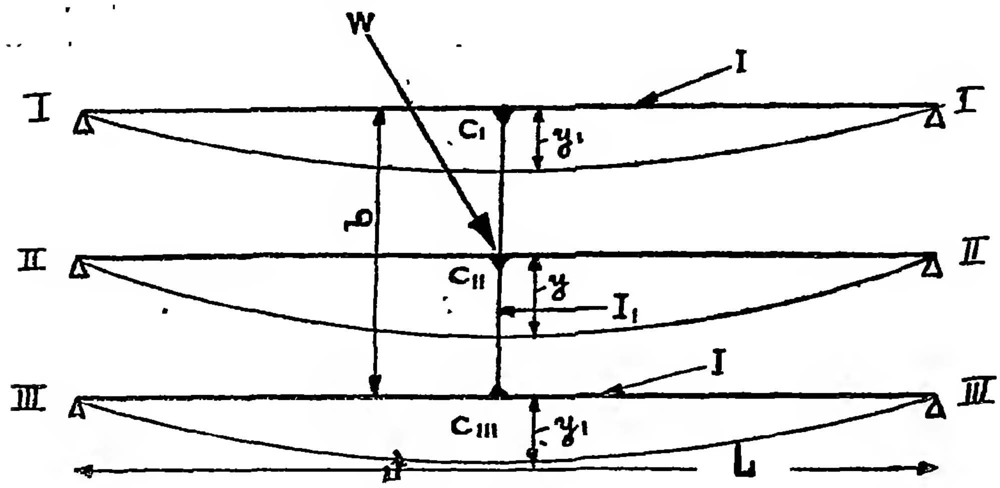


FIG. 6

From the above sketch (fig. 6) it is to be seen that a Stiffener transfers a part of the load W on the beam II—II to the beams I—I and III—III. To find the amount of distribution of the load W in various members is a problem of solving a statically indeterminate structure. We will however try to solve this similar to a system of 3 beams rigidly connected with a stiffener as shown above in points $C_I - C_{II} - C_{III}$. Let us first assume that the Beam I—I is loaded with a uniformly distributed load = WL Fig. 6 (*b*) it is obvious that this load will be distributed in forces Xc_1, Xc_2 and Xc_3 causing simultaneous deflections at points C_1, C_2 and C_3. (Fig. 6 (*a*)).

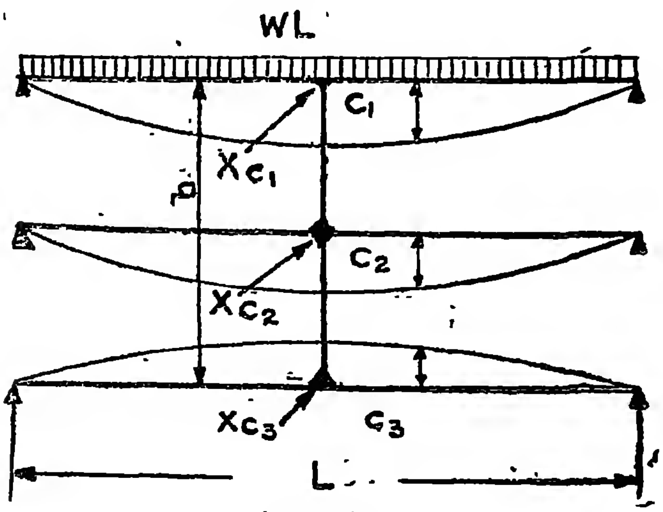


FIG. 6 (*a*).

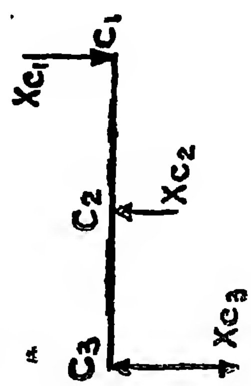


Fig. 6 (*b*)

The stiffener, as shown in the fig. 6 (*b*) may be regarded as a Beam resting on points C_1 and C_3 and consequently due to Equilibrium

$$Xc_1 = Xc_3 = \frac{Xc_2}{2}$$

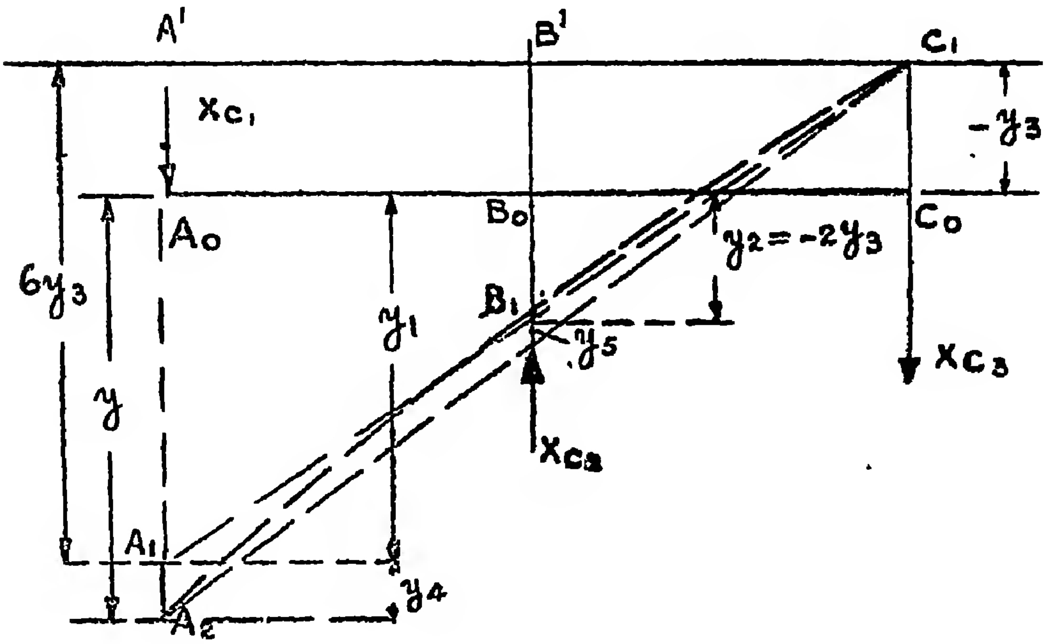


FIG. 7

Due to the free movement the position of the beam may be imagined to be $A_1\,B_1\,C_1$ (Fig. 7) with an uplift of $-y_3$ from points Co to C_1 and a lowering down of point Bo to $B_1 = y_2$ and Ao to $A_1 = y_1$. The downward movement from Ao to A_1 is due to the displacement of the beam without bending. While $A_1\,A_2 = y_4$ is due to bending. Making $A'\,B'\,C_1$ parallel to the original position of the beam Ao Bo Co and with the help of equation of the projected beam we are able to find the unknown forces Xc_1, Xc_2, Xc_3 by the works done during the displacement. As Xc_1 is equal Xc_3 and in joint Bo $Xc_2 = 2\,Xc_3$. The downward movement $y_2 = -2y_3$ and the distance $B_1\,B' = 3y_3$. And therewith $A_1\,A' = 2\,B_1\,B' = 2\times 3y_3 = 6y_3$. Further follows that $Ao\,A_1 = A_1\,A' = Ao\,A' = 5y_3$. Due to bending, the deflection in point Bo is $y_5 = \frac{1}{48}\times 2Xc_1 \frac{b^3}{EI}$

The deflection y_4 in Ao is due to the cantilever force $Xc_1 = \frac{1}{12}\,Xc_1\,\frac{b}{EI}$

The total deflection is $y = 5y_5 + y_4$ or $y_4 = y - 5y_5$

The deflection in C can also be derived from the Elastic Equation

i. e., $y = \frac{5}{384}\cdot\frac{WL^3}{EI} = \frac{1}{48}Xc_1\cdot\frac{L^3}{EI}$; $y_5 = \frac{1}{48}\,Xc_1\,\frac{L^3}{EI}$; $y_4 = \frac{1}{12}Xc_1\,\frac{b^3}{EI_1}$

$$y - y_1 = y_4 = \left(\frac{5}{384}\,\frac{WL^3}{EI} - \frac{1}{48}\cdot\frac{Xc_1L^3}{EI}\right) - 5\frac{1}{48}\,Xc_1\,\frac{L^3}{EI} = \frac{1}{12}\,Xc_1\,\frac{b^3}{EI}$$

making $c = \left(\frac{b}{L}\right)^3 \frac{I}{I}$ we get $Xc_1 = \frac{5}{16}\,WL\,\frac{1}{3+2c}$

The bending moment in the main Beam $1-1$ (fig. 8) will be reduced to

$$BM_{1-1} = \frac{WL^2}{8} - Xc_1\frac{1}{4} = \frac{WL^2}{8}\left(1 - \frac{5}{8(3+2c)}\right)$$

and in beam $(2-2)$ $BM_{2-2} = 2Xc_3\times\frac{1}{4} = \frac{5}{64}\,WL^2\,\frac{1}{3+2c}$

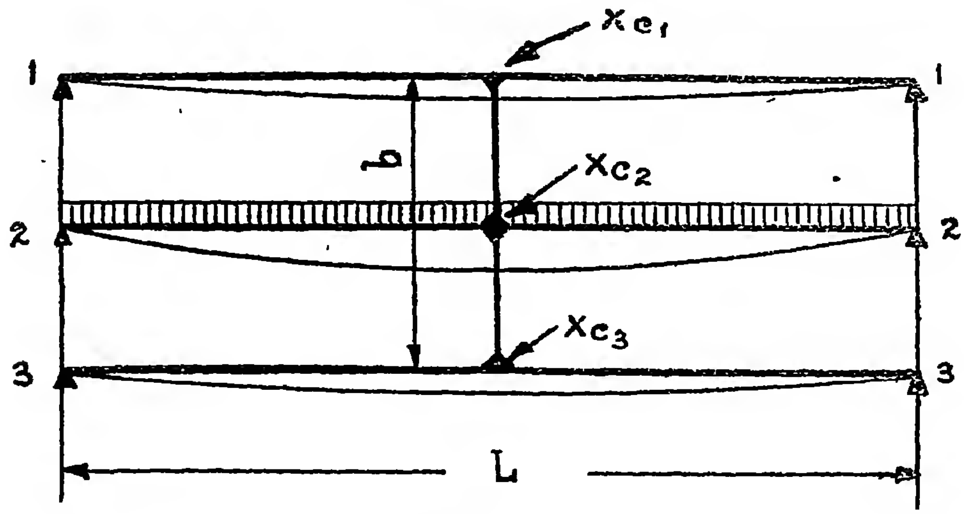
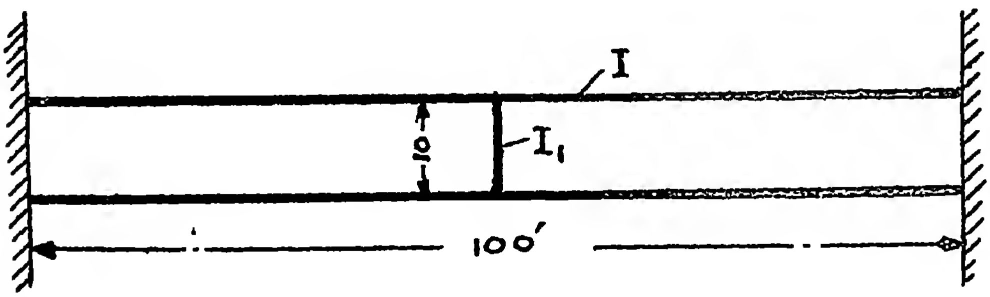


FIG. 8.

In the case when the Middle beam (2-2) is uniformly loaded, we arrive by the same method of analysis to $Xc_2 = \frac{5}{4}$ WL $\frac{1}{3+2c}$ etc. etc.

It is obvious that the Bending Moment obtained by using a stiffener is a function of the rigidity factor C and is equal to $\frac{(b)^3}{L} \frac{I}{I_1}$ and, therefore, depends on its limits. To make it clear let us assume a long span bridge with a narrow deck. Assume also L = 100 feet and b = 10 feet. The rigidity factor $C = \left(\frac{10}{100}\right)^3 \frac{I}{I_1} = 0.001 \frac{I}{I_1}$.

The ratio of $\frac{I}{I_1}$ in Reinforced concrete is generally varying between one and two



i.e. $\frac{I}{I_1} = \frac{2}{1}$ or $= \frac{1}{1}$ and therefore C will, in any case, be negligible and the value of Xc_1 will be $\frac{5}{48}$ WL. We may derive a similar result if we make $\frac{I}{I_1} = \infty$, which signifies that the system is absolutely rigid on account that the moment of inertia of its stiffener being $I_1 = \infty$.

Considering another case, *i.e.*, when $C = \left(\frac{b}{l}\right)^3 \frac{I}{I_1} = 1$ which is possible, when b=l and $I = I_1$, the magnitude of Xc_1 will become $Xc_1 =$ WL$\frac{1}{3+2c} = \frac{1}{16}$ WL or $\frac{3}{48}$ WL.

Execution of the beams and stiffeners.—The casting of beams was made in wooden moulds placed on a rigid staging. The staging was carefully calculated and so designed that no yielding should occur. The calculation of such a staging is rather difficult and very problematic due to the use of varying shapes and sizes of *Sal ballas* which are very rarely absolutely straight. Therefore a high factor of safety had to be allowed.

To avoid leakage through the joints of the moulds and to avoid warping of the planks, the interior was fitted with water-proof paper. It has proved to be successful, not only in the points mentioned but in the curing of concrete too. The surface of the beams appeared to be free of air holes and smooth. There are difficulties in placing the paper when the moulds are already assembled. It is also difficult to supervise the ramming of concrete. The paper must be laid absolutely smooth and must not be damaged when ramming, otherwise a surface of unpleasant design may be expected.

Rockers.—In every cantilever end, a fixed rocker bearing is placed and a bearing which simultaneously rocks and slides, (see plate 4.)

The rocker bearings are made of Cast Iron and are comparatively cheap. A pair of rockers cost about Rs. 20/-. The Rockers are a very important member of a cantilever bridge. The author of the paper knows that when they were not used, the consequences were of most disagreeable and costly nature. The main advantage of a Rocker is to keep the resultant Force in the Cantilever acting vertically and between the calculated limits.

The rockers have been thoroughly greased and covered with a coil of ropes sufficiently greased, so as to prevent penetration of mud and dust.

Slab.—The slab of the bridge is 6 inches thick and is covered with 2 inches concrete road surface resulting in a dead load of a hundred pounds per square foot. The slab is reinforced in transverse direction with 3/8-inch bars 3-inch centres and longitudinally with 3/8-inch bars $4\frac{1}{2}$ inches centres.

The strain in corners has been specially taken up by special diagonal bars according to Marcus Theory which increases the factor of safety to a very great extent. The slab is allowed to expand and contract practically in each span. The expansion joints are clearly shown in plate No. 4. The surface carpet is of a special hard wearing concrete.

Test.—In the beginning of August 1938, the bridge was tested under the following loading :—

(*a*) A 15 tons steam roller preceded and followed by a crowd of 20 men immediately next to the roller.

(*b*) A dead load of 100 pounds per square foot was placed on the road-way on each side of the roller and the whole load was kept on the bridge for about 11 hours.

A theodolite was used for measuring deflection but in both the cases of testing no deflection was observed. A similar bridge *Auranga Bridge* (see plate 5) designed and built by the author showed a deflection of $\frac{1}{7000}$ which was measured with a pendulum The Sai River bridge was executed by Messrs. Bird & Co., and designed by the author of this paper. Lieut-

Colonel, W. de H. Haig, Chief Engineer, Public Works Department, United Provinces, in a well chosen speech referred to the necessity of maintaining and building of R. C. Bridges for communications, one of the latest and the best of which was the Sai Bridge (see plate 6). For this kind remark the author expresses his thanks and attributes the success of this bridge to his remarkable goodwill and collaboration and the helping hand given by the Public Works Department staff. Unfortunately the author could not be present at the time of opening the bridge.

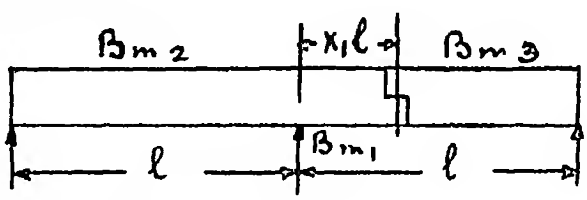
ANNEX

GERBER BEAM.

The Gerber Beam is a System of beams consisting of a slung beam and of a freely supported beam with cantilever ends. The continuation of these two beams is called the Gerber System. A system of beams resting on n supports will consist of (n-2) hinges. The hinges can be made to rotate if a rotating pin is provided. The hinges of this kind are used in steel structure. In reinforced concrete, the hinges are generally made to be rocking and sliding. Pinned hinges are used in reinforced concrete bridges only when they are supposed to be submerged. For computing the stresses in a Gerber System, (n+1) equations will be necessary (n being the number of supports). These (n+1) equations consist of three general equilibrium equations and (n−2) Moments' Equations (M=O). For the sake of economical design, it will be of importance that the cantilever ends, X_1 l, should be made of such lengths that the display of the negative and positive Bending Moments in the members of the system due to the dead and live loads should be of equal amount. To facilitate the calculation of cantilever ends, tables for different amount of supports on spans are as follows. The proof of the formula can be furnished by the author to the members who are interested to have it any time on request. It is understood that in a span, more than 2 hinges should not be provided. The Gerber System, being a statically determinate structure, the calculus does not render any difficulty. It is advisable first to find the reaction coming due to the dead and live loads from the slung beam. The Bending Moments due to the live load on the bearing beams and cantilever should be found with the help of Influence Lines. An example of influence lines for a Gerber System of Beams with unequal spans is shown in plate No. 7 for Kalarpole Bridge near Chittagong.

Assume "W" being the amount of dead load in lbs. ft.
P " " live load in lbs. ft.
Q = W + P = total load in lbs. ft.
Bm = Bending moment.

Cantilever beam on 3 supports



Make $X_1 = \left[\frac{Q}{W}\left(1 - \sqrt{1 + \frac{W}{Q}}\right)\right]^2$ than

$Bm_1 = Bm_2 = \frac{x_1}{2} Q\, l^2$

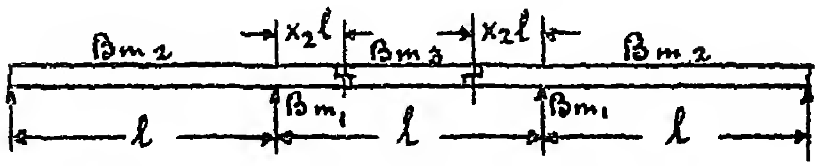
If only "Q" is to be taken into account

make $X_1 = 0.1716\,l$ than

$Bm_1 = Bm_2 = Bm_3 = 0.0858\,Q\,l^2$

4 supports

Arrangement (a)



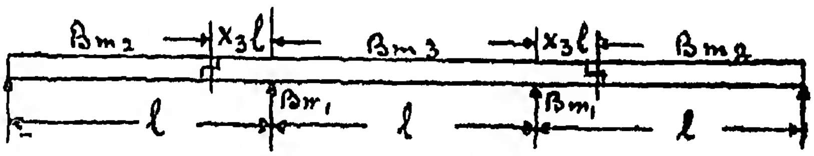
Make $X_2 = \frac{1}{2}\left(1-\sqrt{1-4X_1}\right)$ than $Bm_1 = Bm_2 = \frac{X_1}{2}\,Ql^2.$

$$Bm_1 = \frac{Ql^2}{8}\left(1-2X_2\right)^2$$

If only "Q" is to be taken into account

make $X_2 = 0.221$; $Bm_1 = Bm_2 = 0.0858\,Ql^2$; $Bm_3 = 0.0392\,Ql^2$.

Arrangement (b)



Make $X = \frac{Q}{4(Q+w)}$ than $Bm_1 = Bm_4 = \frac{Ql^2}{2} X_3$; $Bm_2 = \frac{Ql^2}{8}(1-X_3)^2$

If only "Q" is taken into account

make $X_3 = 0.125\,l$ than $Bm_1 = Bm_4 = 0.0625\,Ql^2$

$Bm_2 = 0.0957\,Ql^2$

If it is desirable to make $Bm_1 = Bm_2$ than make

$X_3 = 3-2\sqrt{2} = 0.1716\,l$, than.

$$Bm_1 = Bm_2 = \frac{Ql^2}{2} X_3 = 0.0858\,Ql^2$$

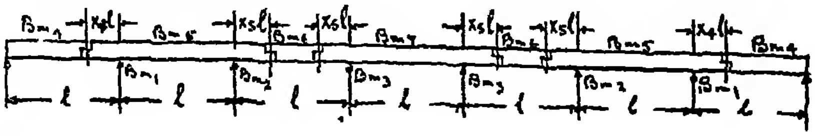
$$Bm_4 = \frac{Ql^2}{8}\left(\frac{Q}{W} - 4X_3\right)$$

If only "Q" is to be taken into account make:

$X_3 = 0.1716\,l$; $Bm_1 = Bm_2 = 0.0858\,Ql^2$; $Bm_3 = 0.0392\,Ql^2$

Cantilever system on several even number of supports or odd number of spans.

Cantilever arrangement (a)



Make $X_4 = \dfrac{Q}{4(Q+W)}$. and make $X_5 = \frac{1}{2}\left(1 - \sqrt{\dfrac{Q}{Q+W}}\right)$

than $Bm_1 = Bm_5 = Bm_3 = Bm_2 = Bm_7 = \dfrac{QX_4 l^2}{2}$

$Bm_6 = \dfrac{Ql^2}{8}\left(1 - X_4\right)^2$ and $Bm_6 = \dfrac{Ql^2}{8}\left(1 - 2X_5\right)^2$

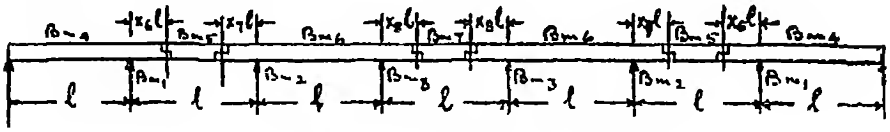
If only Q to be considered than make

$X_4 = 0{\cdot}125\, l$ and $X_5 = 0{\cdot}1465\, l$

than $Bm_1 = Bm_5 = Bm^2 = Bm_7 = Bm_3 = Bm_6 = 0{\cdot}0625 Ql^2$

$Bm_4 = 0{\cdot}0957 Ql^2$

Cantilever arrangement (b)



Make $X_6 = \frac{1}{2}\left[1 - X_4 + X_1 - \sqrt{(1 - X_4 + X_1)^2 - 4X_1}\right]$

$X_7 = \dfrac{X_1}{1 - X_6}$; $X_8 = X_5$

than $Bm_4 = Bm_1 = \dfrac{Ql^2}{2}(1 - X_7)X_6$

$Bm_2 = Bm_6 = Bm_3 = \dfrac{Ql^2}{2} X_8 (1 - X_8)$

$Bm_5 = \dfrac{Ql^2}{8}(1 - X_6 - X_7)^2$;

$Bm_7 = \dfrac{Ql^2}{8}(1 - 2X_8)^2$

If only Q to be considered

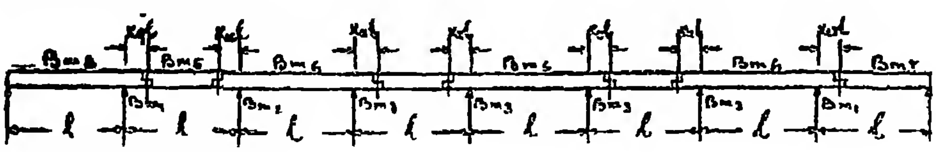
$X_6 = 0{\cdot}2035$ $Bm_4 = Bm_1 = 0{\cdot}0858\ Ql^2$

$X_7 = 0{\cdot}157$ $Bm_2 = Bm_6 = Bm_3 = 0{\cdot}0625\ Ql^2$

$X_8 = 0{\cdot}1465$ $Bm_5 = 0{\cdot}05112\ Ql^2$

$Bm_7 = 0{\cdot}0695\ Ql^2$

Multiple cantilever system of odd number of support and even number of spans.



Make $X^9 = X_6$

$X_{10} = X_7$

$X_{11} = X_5$

$X_{12} = X_4$

than $Bm_4 = Bm_1 = \frac{Ql^2}{2} X_9 (1 - X_{10})$

$$Bm_2 = Bm_6 = Bm_8 = \frac{Ql^2}{2} X_{11}(1 - X_{11})$$

$$Bm_5 = \frac{Ql^2}{8} (1 - X_9 - X_{10})^2$$

$$Bm_7 = \frac{Ql^2}{8} (1 - 2X_{11})^2$$

For Q only

$X_9 = X_6 = 0{\cdot}2035$ $\quad Bm_4 = Bm_1 = 0\ 0858\ Ql^2$

$X_{10} = X_7 = 0{\cdot}157$ $\quad Bm_2 = Bm_6 = Bm_7 = 0{\cdot}0625\ Ql^2$

$X_{11} = X_8 = 0{\cdot}1465$ $\quad Bm_5 = 0{\cdot}05112\ Ql^2$

$X_{12} = X_4 = 0{\cdot}125$

PLATE 5. AURANGA BRIDGE,
District-Palamau.
(Completed in 1937)

Total Length=560′-0″ Width=16′-0″ Central span=72′-0″ End span=60′-0″

PLATE 6. SAI BRIDGE.
Completed in 1938.

DISCUSSIONS ON PAPER D—1939.

Dr. M. A. Korni (Author) :—I quite realise how unpleasant it must be to listen to an oration rendered in broken English and a foreign accent and I, therefore, tender my apologies to the Congress for any faults I may make in my speech, and will try to introduce my paper in as short a manner as possible.

The Sai Bridge is a typical cantilever, or better expressed, a Gerber bridge, and should not be parelleled with the type of bridge like the Firth of Forth Bridge, as this bridge consists of a pier which is extended by a steel structure with two arms on which a slung span is resting as shown in the sketch.

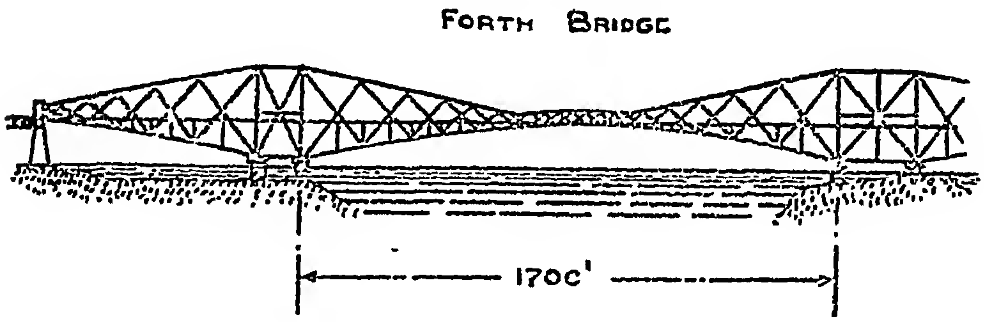


FIG. 9

A Gerber bridge is built in such a way that the negative Bending Moments produced by the slung span in the cantilever reduce the Positive Moment in the middle span, thereby affecting an economy in materials

A similar bridge, which was the first bridge of this type which I built in India, was, as far as I remember, described in 1927 in an issue of the Indian Concrete Journal. Since then, I have been fortunate enough to build several bridges which have proved to be successful. I need only mention the Auranga bridge, which is of a similar type to the Sai Bridge. I was also extremely fortuuate in having Mr. Murrell over me when he acted as Superintending Engineer for the Government of Bihar. Mr. Murrell was very helpful with suggestions, all of which were brought into use. These improvements, which involved extra cost, were at the same time worth the money spent on them. But, as it often happens, the contractor, due to keen competition, is bound to make omissions in order to make the tender more attractive and it is left entirely to the Superintending Engineer to call for certain improvements.

It is obvious that in certain districts, lime mortar used in piers is much cheaper than any imaginable and practical cement motar mixture and although I would like to see a bridge made entirely of cement, there

are cases where the dictator is "Mr. Economy" and the contractor is forced to obey his orders and build the piers with lime mortar. Moreover, not much can be said against this binder of a very old and good reputation. It is often that failures are mistaken and the wrong component in a structure blamed. For example, a certain pier in India built of bricks laid in lime mortar showed that this pier could not be used for a heavier railway load, as the crushing stress of the bricks near the bed of the river had already made its appearance, but the mortar was intact. In view of this there seems to be very little objection against the use of lime mortar in piers although some of the engineers do object to it. And if the Amanat Bridge was laid on cement mortar, an extra amount was paid for it, which the Sai Bridge could not afford to do. Both bridges are equally good and sound.

You may have noticed the method of testing the soil under the wells. This method is well worth mentioning as it is an important point which I wish to mention in introducing the paper. Originally, it was contracted to test the ground after the piers had been erected on the sunk wells. This would have meant that a load of 320 tons would have been brought on each well before testing the ground. Naturally this spelt a very costly item to the contractors and it would have been still costlier had the foundations failed. Their thanks are due to the Chief Engineer who agreed to the proposal of testing the soil inside the wells before the erection of the piers. Consequently a difficult task of ground improvement in well No. 7 was easily overcome as described in the paper. This method is very much in use on the Continent and was jointly described by Mr. John Chambers and myself in articles on "Modern Methods of Construction and Designs of Foundation" in "Indian Engineering" of November 1930.

The behavior of the wells No. 7 and 8 is exhaustively described in the paper on pages 6 (*d*) and 7 (*d*) and it is to be hoped that engineers will take advantage of this cheap and effective method of testing the foundations.

Another item of interest in this paper is the formulæ for calculating the thickness of steining of brick wells or stone masonry wells. This item has been given in response to the demand of various engineers of the Public Works Department all over the country. To simplify the formula, ratio of the weight or specific gravity of water and earth which is one to two, has been used

To demonstrate the use of this formula the following dimensions and conditions have to be assumed beforehand :

(*i*) The inner radius of the well — " r ",

(*ii*) The safe stress of the bricks or stone — " f ", and

(*iii*) The depth to which the well is expected to be sunk — " h "

Assuming " r " = 4.5 feet

" f " = 6 tons per square foot, and

" h " = 30 feet.

The external radius $R = 4.5\sqrt{\dfrac{6 \text{ Tons}}{6 \text{ tons} - 0.09 \text{ p in tons}}}$

as $p = \frac{5}{4} h = \frac{5}{4} \times 30 = 37.5$ tons and

$0.09 p = 0.09 \times 37.5 = 3.375$ tons

$$R = 4.5\sqrt{\frac{6}{2.625}} = 6.75 \text{ feet}$$

The thickness $t = R - r = 6.75 - 4.5 = 2.25$ feet

say $2\frac{1}{2}$ bricks

The third item of importance in the paper that might be mentioned is the design of the cantilever ends of the Sai Bridge to which subject nearly half of the paper has been devoted, [pages 9 (*d*) to 16 (*d*)]. The detailed calculations are accompanied by several drawings, tables and diagrams. The reason for this elaboration is to impress on engineers that this part of the bridge can lead to very dangerous consequences if not thoroughly analysed and computed. I have just been to the site of a Gerber bridge that has proved a failure. This bridge, which consists of 23 spans and is half a mile in length is under repairs of a very costly nature. It was discovered soon after its completion that in every end of the cantilever corner, cracks had appeared in the angle of re-entrance. This confirms the theory that diagonal stresses are produced and must be overcome by special steel reinforcements. That stresses under an angle of 45 degrees to the horizontal axis should take place, is due to the sudden changes in thickness in the cantilever End. These stresses are similar to those produced in objects made of cast iron where a sudden change in masses cannot be avoided.

The item dealing with transverse beam may be new to many engineers in India. It is only a few years since the Continental engineers have seriously taken up analysing the effect of the rigid connection on a tranverse beam on the main girder. Much economy is gained when the dispersion of bending moments through the rigid connection is taken into consideration.

I hope that the formula for the different arrangements of gerber beam bridges will be of use to the designer and to the engineer in checking or deciding the economical length of the cantilever in a Gerber structure when they decide to adopt this type in bridge design.

I thank you, Mr. President, Mr. Chairman and gentlemen for your patience in listening to my introduction of the paper entitled "the Sai Bridge".

S. B. Joshi (Bombay) :—The author is a well known designer in India and I do not think he is in need of any complimentary remarks from me. As the time available is short I will restrict myself to the criticism of some of the important disputable points in the paper.

I first refer to pages 9 (*d*) to 15 (*d*) where the author has given his analysis of the design of the cantilever ends. He says that the most dangerous section in a cantilever is the angle of re-entrance. Ordinarily there should not be any difference of opinion between two engineers on theoretical questions ; but I have great doubts about the correctness of the treatment by the author of the re-entrant angle.

It will be seen from the table on page 11 (d) that the author has used the expression $\frac{Bm}{Z}$ for finding the maximum stress in a section. But the relation $\frac{Bm}{Z}$ = stress is based on the fundamental theory of bending which assumes that $\frac{1}{R} = \frac{M}{E\,I}$ and that the sections under consideration are radial sections *i e.* they pass through the instantaneous centres of curvature at different points along the Beam. The relation $\frac{Bm}{Z}$ = stress cannot apply to random sections. And the author has taken five vertical sections and four inclined sections passing through the point A. Obviously the author's inclined sections do not satisfy the conditions stated above and the equation $\frac{Bm}{Z}$ = stress cannot be applied in case of these sections.

The fallacy of taking random sections—five vertical and four inclined sections concurrent at the point A, will be clear if we try to trace the netural surface by joining the neutral points of all these sections. Any attempt to get 'one' neutral surface fails. There is one neutral surface for the vertical sections and another one for the inclined sections. This is absurd.

It should also be noted that the stress given by the equation $\frac{Bm}{Z}$ = stress at the fibre-gives the Principal stress in the material at the edge of the section - both in magnitude and direction. Author's section IV and section VII nearly start from the same point of the Beam, but are inclined to each other. According to the author's treatment—we get two Principal stresses at this point inclined to each other. This again brings us to an absurdity—because the sections taken by the author are not the proper ones In fact, the stresses found by the author are not the maximum fibre stresses in the material at the edge of the inclined sections and are not the principle stresses.

The author has found out by graphical methods that section number VIII which is inclined at 30 degrees to the vertical is the worst section.

Assuming, for the sake of argument, that the author's method of analysing inclined sections is correct, let us try to find out the worst section mathematically.

Let the worst section be inclined at ϕ with the vertical.

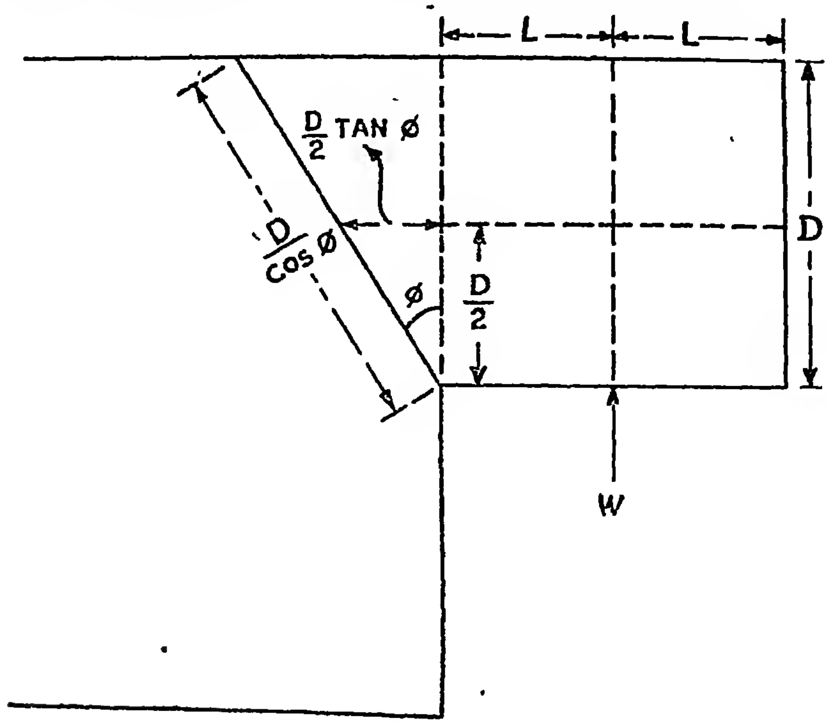


FIG. 10 .

Therefore, the depth of the worst section is $\frac{D}{\cos\phi}$ and its breadth is B say.

$$\text{Modulus of Section, } Z = \frac{bd^2}{6} = \frac{B}{6} \times \frac{D^2}{\cos^2\phi}$$

$$\text{Bending Moment} = W\left(L + \frac{D\tan\phi}{2}\right)$$

$$\therefore \quad \text{Stress} = \frac{Bm}{Z} = \frac{\left(L + \frac{D\tan\phi}{2}\right)}{\frac{BD^2}{6\cos^2\phi}}$$

$$\therefore \quad F = W\left(\frac{6\,L\cos^2\phi}{BD^2} + \frac{D\tan\phi \times 6\cos^2\phi}{2\,BD^2}\right)$$

$$= W\left(\frac{6\,L\cos^2\phi}{BD^2} + \frac{3\sin\phi\ \cos\phi}{BD}\right)$$

$$= W\left[\frac{6\,L}{BD^2}\left(\frac{\cos 2\phi + 1}{2}\right) + \frac{3\sin 2\phi}{2\,BD}\right]$$

$$= W\left[\frac{6\,L\cos 2\phi}{2BD^2} + \frac{6\,L}{2BD^2} + \frac{3\sin 2\phi}{2\,BD}\right]$$

$$\therefore \quad \frac{dF}{d\phi} = W\left(\frac{-6L}{2BD^2} \times \frac{2\sin 2\phi}{1} + 0 + \frac{3 \times 2\cos 2\phi}{2\,BD}\right)$$

For F to be maximum, put $\frac{dF}{d\phi} = 0$

$$\therefore \frac{-6L \sin 2\phi}{BD^2} + \frac{3 \cos 2\phi}{BD} = 0$$

$$\because \tan 2\phi = \frac{3}{B.D} \times \frac{BD^2}{6L} = \frac{D}{2L} \text{ [If } \cos 2\phi \neq 0 \textit{ i.e. } \phi \neq 45^\circ\text{]}$$

$$\therefore \qquad \phi = \tfrac{1}{2} \tan^{-1} \frac{D}{2L}$$

Author's figures 1 and 2 give

D = 28" and L 12"

$$\therefore \qquad \phi = \tfrac{1}{2} \tan^{-1} \tfrac{28}{24} = \tfrac{1}{2} (49^\circ - 24')$$

$$= 24^\circ - 42'$$

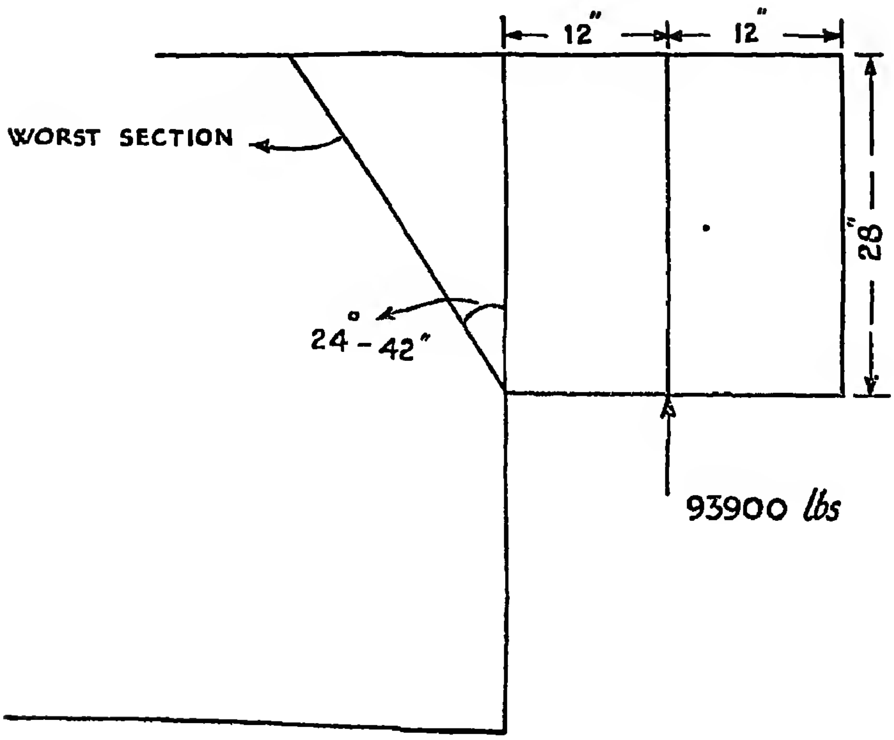


FIG. 11

This gives $\frac{Bm}{Z} = \frac{1731469}{2528.6}$ 684.7 pounds per square inch.

The equation $\phi = \frac{1}{2} \tan^{-1} \frac{D}{2L}$ shows that the position of the worst section is a function of D and L only. Thus in Fig. 12 whether the section suddenly changes from 58 inches to 28 inches or from 78 inches to 28 inches, the position of the worst section is always inclined at $24^\circ - 42'$ with the vertical. That means the position of the worst section is independent of the extent of the suddenness with which the sectional area at the ends of the cantilever changes

In fact, if the section changes from 29 inches to 28 inches the position of the worst section will, even then, be at 24°—42′ with the vertical.

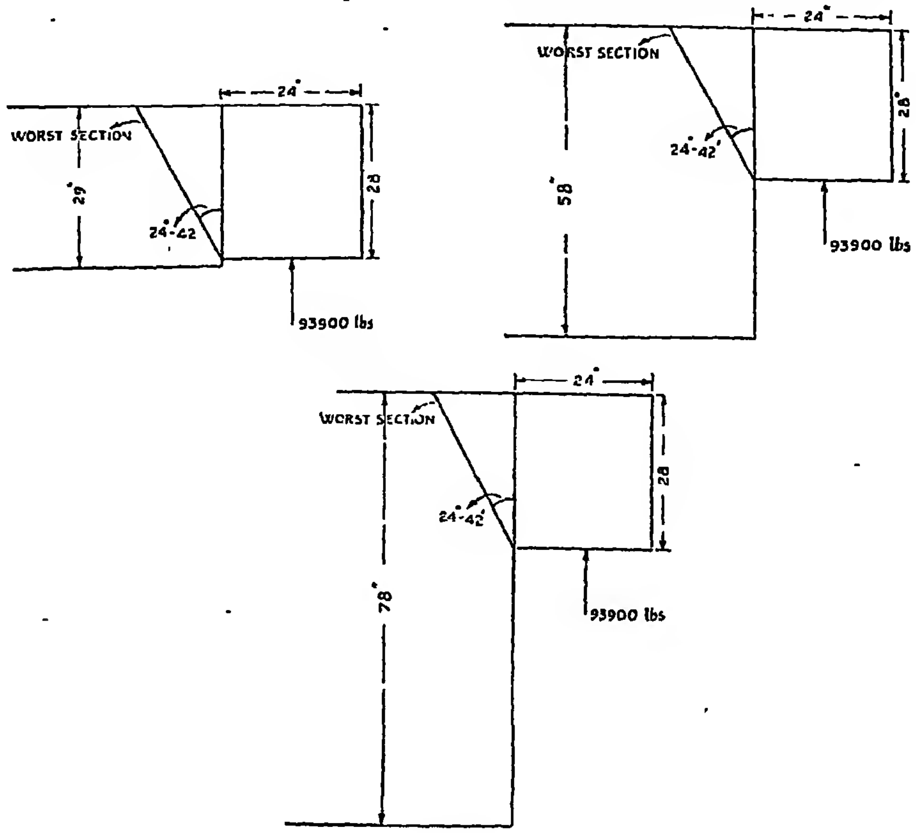


FIG. 12

This leads us to the conclusion that the author's method of taking inclined sections and finding the position of the worst section has nothing to do with the sudden change in the sectional area at the ends of the cantilever. But the author starts his analysis by the statement that "the cause of extraordinary stresses is the sudden change in the sectional area at the ends of the cantilever." This clearly shows that the author's method of taking inclined sections passing through A is not correct.

Similarly the author could have found the maximum shear without reference to inclined sections. The maximum shear is obviously on a vertical section 28″ × 16″ just to the left of Section II giving a stress of $\frac{93900}{28 \times 16 \times 0.87} = 240$ pounds per square inch.

The author is perfectly right in drawing the line A B at 45 degrees to the vertical. (See his Fig. 2)

The tensile stress at A will be connected to the stress at B, through the body of the beam only by an inclined line like A B. The proper way is to take vertical sections, and the pull F at the extreme end of the vertical section can be provided for by reinforcement along A B, having a sectional area sufficient to withstand a force equal to F sec. 45°, *i.e.*, 1.41 F.

I now refer to page 4(*d*) where the author has given the formula $R = r\sqrt{\frac{6 \text{ Tons.}}{6-0.09\ p}}$. It is difficult to imagine how the author derived this formula. If the theory of thick cylinders is to be applied, Lame's equagives us the maximum stress in the cylinder wall

$$= \frac{2\ FR^2}{R^2 - r^2} \text{ when the internal force is put equal to zero.}$$

$$\therefore 6 \text{ Tons} = \frac{2\ FR^2}{R^2 - r^2}$$

$$\therefore R^2 (6 \text{ Tons} - 2\ F) = 6\ r^2$$

$$R = r\sqrt{\frac{6 \text{ Tons}}{6 \text{ Tons} - 2\ F}}$$

The author gives 'p' in terms of equivalent column of water expressed in feet. So I presume that the dimension of 'p' in the author's equation is 'Length'. If it is to be converted into equivalent force in tons per square foot, it must be multiplied by $\frac{62.5}{2240}$.

$\therefore$ The equation $R = r\sqrt{\frac{6 \text{ Tons}}{6 \text{ Tons} - 2\ F}}$ can be converted into

$$R = r\sqrt{\frac{6 \text{ Tons}}{\frac{2 \times 62.5}{} \ p}}$$ where p is in equivalent head of water expressed in feet.

$$\therefore R = r\sqrt{\frac{6 \text{ Tons}}{6 - 0558\ p}}$$

This does not exactly tally with the author's equation.

I can arrive exactly at the author's equation by guess work, by assuming the empirical formula given in Molseworth's hand-book, and by further assuming that the author has taken a margin of safety equal to 2.

Putting external pressures equal to zero, the empirical formula in Molseworth's hand-book gives tangential stress $= \frac{5\ FR^2}{3\ (R^2 - r^2)}$ where F is the external pressure.

$$\therefore 3 \text{ Tons} = \frac{5\ FR^2}{3\ (R^2 - r^2)}$$

$$R^2 (9 - 5\ F) = 9\ r^2$$

$$\therefore R = r\sqrt{\frac{9}{9 - 5\ F}}$$

$$= r\sqrt{\frac{6 \text{ Tons}}{6 \text{ Tons} - \frac{10}{3}\ F}}$$

Writing $F = \frac{62.5}{2240}$ p, we get

$$R = r\sqrt{\frac{6}{6 - \frac{10}{3} \times \frac{62.5}{2240}\,p}}$$

$$= r\sqrt{\frac{6}{6 - 0.093\,p}}$$

This exactly tallies with the author's equation given on page 4(*d*).

It would have been better if the author had given the derivation of his equation. It would not have led his readers guessing. The equation as it stands without any explanation looks dimensionally wrong.

The author is not right in putting W=1 in his equation for P on page 4 (*d*). He possibly wants to express p in equivalent feet of head of water in which case $p = \frac{5}{4}h$ — where p is in feet of head of water.

I will now deal with the other minor points in the Paper page by page.

On page 1 (*d*), the author gives the crushing strength of concrete used for Reinforced Cement Concrete slab on top of piers as 1200 pounds per square inch. This concrete is too lean and cannot possibly be expected to give a sufficiently good mix to develop proper bond which is so necessary for Reinforced Concrete work.

On page 1 (*d*) and 2 (*d*), the author has given the quantities of work for use of Bridge designers. I would like to know the quantity of steel required in slabs and beams.

On page 3 (*d*), under '*geological formation*' the author uses the word 'Elastic Prop'. I wish to emphasize that there is nothing common between an Elastic Prop and a Yielding foundation.

The author attributes the 'thinning out' of the *kankar* strata, in the middle of the river, to 'violent deterioration'. I do not think there is any organic deterioration The strata in the middle of the river has obviously thinned out due to wear caused by the force of water of the stream.

On page 4 (*d*), the author has given a series of reasons in favour of the use of a circular well. I would add one more reason. A circular shape gives the least perimeter for the same area and the pressure required to overcome friction in sinking the well is the least. It should not require much effort to convince the Public Works Department engineers, that circular shape is preferable to other shapes of wells.

On page 5 (*d*), the author ignores the horizontal pressure in designing Reinforced Cement Concrete well kerbs. This is objectionable.

In the table given on page 9 (*d*), the author gives the live load Bm in the centre as + 875000, — 875000, + 634600 and — 634600. Surely there must be some misprint. How can there be four alternatives. Does the author mean + 875000 foot pounds. or — 634600 foot pounds.

It is clear that if the Central Beam is to be subjected to either positive or negative bending moments, the beam cannot be designed as a T-beam to utilize slab as a compression flange.

On page 11 (*d*)—foot note, the author says that 281700 inch pounds is the Bending Moment due to expansion and contraction. His calculations for this foot-note on page 12 (*d*), do not show any connection of this Bending moment with expansion and contraction.

I thank the author for his very interesting paper, which with all its drawbacks, is very useful to every bridge designer.

Mr. W. L. Murrell (Bihar):—I have had some personal experience of the type of bridge described by Dr Korni, which may be of interest.

But first I would like to remark that I am not sure that clay and *kankar* are sufficiently stable ground on which to found a comparatively heavy bridge of this type.

In the Chota Nagpur Circle there have been two cases in fairly recent years where the piers of major bridges carried on twin piles took a tilt up-stream, owing, doubtless, to some trouble developing at the foot of the up-stream well some years after erection. One was a large and important highway bridge founded on soft rock and clay. The other was a railway bridge founded on soft sand-stone.

It was fortunate that in each case the freely supported superstructure was of steel, so that the spans effected by the faulty pier could be traversed back into alignment and placed on realigned and relevelled bearings.

If this sort of thing happened to a bridge of the type now under discussion, there would soon be a rather bad mess. In the first place, both the main and the slung spans would be placed into more or less severe torsion, and then the gaps between the main beams and the slung beams along one side of the bridge would close up and there would be a bad temperature effect. Only 3 inches out of alignment of the pier-caps in the case of the Sai Bridge would result in this.

Since seeing those tilted piers in Chota Nagpur, I have always specified, when calling for competitive designs and tenders for a bridge not founded on solid rock, that all spans must be freely supported over piers, and that each span must be capable of being lifted from the top of its piers and traversed if necessary.

Some engineers, especially if on short contract with a competitive contracting engineering firm, may smile at such a counsel of safety. But it is one thing to be a designing engineer attached temporarily to a firm that designs bridges, and quite another to be a Government servant who may be called to account ten years afterwards. It is practically impossible to extract and reconstruct a deep well, and two new spans of different lengths on a new pier would look pretty bad, to say nothing of the expense.

On page 7 (*d*), the author mentions bond rods and bond plates. It may be of interest to mention that in the case of the Amanat bridge, not far from the Auranga bridge, copper-bearing steel in 2 : 1 cement mortar

was specified for all steel work embedded in the well masonry, as an anti-corrosion measure. The small increase in cost seemed worth it.

The point is not so much whether the piers will stand, as whether they will stand 100 years. How often are new girders put on old piers!

Dr. Korni's calculations may be exceedingly interesting, but I should like to mention a few practical points with regard to bridges of this type. The type is now very popular in America, where they are using steel joists with a reinforced concrete deck, either acting independently or as composite beams. The slung beams are suspended from the cantilever ends of the main beams by simple steel links. I remember seeing this in the *Engineering News Record* of 31st March, 1938. The Australians and one firm in India are following the Americans, adopting link suspension rather than hinges as mentioned by the author on page 8 (*d*) of his paper.

I have not yet seen the author take full advantage of the economy possible by this type of construction.

Plate 3 of the paper shows shore spans half freely supported. Why should the piers not be so arranged so that the end piers are sited, say, half way up the bank on each side of the river, with the beams cantilevered out over the upper part of the bank? (*See Fig. 13*).

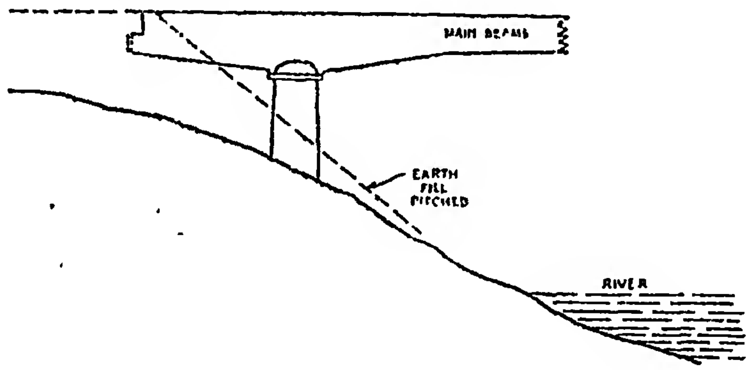


FIG. 13.

This arrangement has some great advantages.

(1) It decreases the cost of the superstructure.

(2) It dispenses with the necessity for wing walls which are expensive on high approaches. It also saves the cost of wells for these wing walls, in some cases.

(3) It enables another span to be added quickly and without waste of wing walls in case the river makes another span necessary. (The Guli Bridge in Chota Nagpur is a good example of this.)

On pages 9 (*d*) and 10 (*d*) etc., and on plate 4, the author deals with the problems of shear and expansion. I was in charge of the Chota Nagpur Circle when the Auranga Bridge was founded, erected and tested. The contract design was for concrete-to-concrete bearings at the ends of the slung spans—but the contractors were given sketches of a bearing never yet used, as far as I know, and they adopted the idea without charge

for extras. The sliding rocker bearing seen on plate 4 is the same as that used on the Auranga bridge except for the ½-inch plate below, the reason for which I would like to know. The upper portion of the bearing rotates about the segmental portion, which in turn can slip backwards and forwards. Thus deflection and expansion are catered for in a bearing only a few inches high.

The next difficulty met with at the Auranga Bridge was in concreting round the reinforcement similar to that shown in plate 4. The contract design was for straight sides to the web, and no splay as shown on page 10 (*d*). Even though we reduced the size of the aggregate by half and enriched the mix in order to make it more workable, we could not properly place the concrete owing to the high concentration of steel in a small space as shown in plate 4.

The only thing that remained to be done was to open out the steel by splaying the web forming of the beam as shown on page 10 (*d*). Of course the outer bars had to be bent out to the splay, thus introducing a tendency to split the web axially in a vertical plane. The stirrups seem to have looked after this tendency, however, in the case of the Auranga Bridge.

Top plan of B, plate 4, shows additional bars instead of bending the outer bars of the Sai Bridge outward to the splay. This is better, but the bars look too short to develop much of their strength.

On page 16 (*d*), the author states that many of us do not realise the value of intermediate cross-beams. Personally, I think he has over-rated their importance. By using "stiffeners" in structures with two main beams, neither beam can be made to help the other. Where there are three more main beams, the outer beams help only the central beam or beams, and then only when the isolated wheel load is well away from the kerb. With our knife edge load as described in our Specification and Codes, the stiffeners or intermediate cross-beams have no design value whatsoever. I would not suggest who is wrong, the author or the Congress Code.

On page 20 (*d*), the author has described the use of wooden forms inlaid with water-proof paper. My experience is that it is better to use thin steel plates for forming the sides of the beams, as far as possible. The finish is better and the anxiety of all concerned while placing the concrete is reduced enormously. Herein lies one great argument for the standardisation of design of Reinforced Concrete Bridges.

I can vouch for the excellent test results of the Auranga Bridge. It is true that, owing to weak bridges *en route* we could not get steam rollers on to the bridge; but the equivalent dead loading by placing sand bags of known average weight on platforms on supports to represent wheels, was relentless. Special regard was paid to putting the "rollers" wholly on the slung span, with hind wheels only a few feet away from the bearings of the slung beams.

It would be interesting to know from Dr. Korni the mix in beams, slab, and road-way wearing surface for the Sai Bridge.

The expansion joints in the road-way of the Auranga Bridge, consisted of simple vertical spacing between the ends of the adjacent slabs

and beams, filled with a bituminous filler. They later gave a good deal of trouble under steel tyres by the concrete edges shearing off at about 45 degrees to a side of 2 or 3 inches.

Rai Bahadur S. N. Bhaduri (Chairman):—We will now adjourn for lunch and meet again at 2-30 p.m. to continue the discussion.

(The meeting was adjourned till 2-30 p.m.)

(The discussions were resumed at 2-30 p.m., with Rai Bahadur S. N. Bhaduri in the Chair.)

Mr. S. A. Shareef (Hyderabad-Deccan) :—In connection with the very interesting paper of Dr. Korni, I would like to make a few observations.

Firstly, it is stated that the river has a catchment area of 4,272 square miles with a maximum flood discharge of 181,810 cusecs and that the average velocity observed during the highest flood on September 23, 1935, was 4.8 feet per second. From the cross section of the river given in plate 3, it is found on a rough approximation that the area of the section at High Flood Level, R. L. 93 89 is about 9,042 square feet. With the flood discharge of 181,810 cusecs, the average velocity works out at 20.1 feet per second, which no soil can stand. Some more details would be interesting on this point.

The flood discharge of 181,810 cusecs for a catchment area of 4,272 square miles gives the value of 'C' in the Dicken's formula as 344. As the value of 'C' in the Dicken's formula varies from 150 to 1,600, it is really very difficult for an engineer to choose a proper value for such a wide range. With Nawab Ali Nawaz Jung's formula $Q = 1{,}500\, M^{\cdot 89 - 1/15 \log M}$ where M is the catchment area in square miles, the maximum flood discharge in the present case works out to 337,800 cusecs. I do not know what formula has been used by the author for calculating the flood discharge of the river and whether the discharge is based on actual gaugings.

At the fourth session of the Indian Roads Congress held at Hyderabad (Deccan), Mr. W. L. Murrell, discussing Mr. Dildar Hosain's paper on the Shahgadh bridge, said that the Indian Roads Congress should issue something authoritative to assist us in the calculation of peak discharges. Any great mistake due to a wrongly used high flood formula may involve not merely inaccuracy but danger to works, property and life. I therefore, suggest that in the absence of reliable records of the gauging of the river for at least twenty-five years we must have some suitable curves to guide us in solving such problems.

With regard to the design of the Reinforced Cement Concrete decking consisting of beams and slab, it is seen that the spacing of the girders from centre to centre is 7 feet 10 inches with overhanging ends of 3 feet 2 inches each. Testing the thickness of continuous slab for shear for the cantilever portion as per Indian Roads Congress loading, the stress works out to 86.5 pounds per square inch, which is obviously inadmissible. I may add here that the shear thus worked out by me is by treating the slab as continuous.

Mr. Brijmohan Lal in his paper on the design of Reinforced Concrete Bridges, which was read at the Fifth Indian Roads Congress, has stated

(*vide* Table III, page 20 j), that for an effective span of 8 feet the thickness of the slab should be $9\frac{1}{2}$ inches. Besides for an effective span of 5 feet 6 inches between beams, the thickness of slab worked out by him is $7\frac{1}{2}$ inches against 6 inches given by Dr. Korni for an effective span of 7 feet 10 inches. As any savings in the thickness of slab will appreciably affect the cost of the bridge, I would request Dr. Korni to enlighten us as to how the thickness of 6 inches has been worked out.

Further, the slab is stated to be reinforced in both directions. It is not clear what part is played by the longitudinal bars $\frac{1}{4}$-inch diameter placed at $4\frac{1}{2}$ inches centre to centre. What is needed in this direction is distribution reinforcement only, as the length of the slab is comparatively much larger than the width for any load to be taken as acting in that direction.

With regard to the design of the main beams, it is noticed that the author has taken several inclined sections into consideration and ultimately a section inclined at 30 degrees to the vertical is shown to produce maximum compressive and tensile stresses. In this connection, I would request the author to enlighten us whether it is possible to calculate the exact angle at which a plane subjected to maximum stress is inclined.

On page 8 (*d*) of the paper, in showing the comparative merits of the 'Gerber System,' the author has stated that the bridge is not affected when the foundation under a pier is yielding. This point requires to be further explained, as with the subsidence of any one pier, at least the continous span is likely to be affected, because the ends are embedded in masonry.

I am of opinion that a 2-inch thick wearing coat as provided in the design is inadequate as it would need frequent renewals. It is usual to provide a cement concrete wearing coat of 3 inches and sometimes of even 4 inches thickness.

Mr. N. Durrani (Madras) :—In the first para on page 1 (*d*), hand rails consisting of Mild Steel angle iron uprights $3\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ at 7.17 pounds and $1\frac{1}{2}$ inches External diameter galvanized pipe rails have been provided. I suggest $4'' \times 2''$ at 7.09 pounds channels for uprights and $3\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ at 7.17 pounds angle iron for top rail and simply two lines of $2'' \times \frac{1}{4}''$ iron flats for the centre for the following reasons.

Comparing the channel and the angle for the uprights the moments of inertia for either are 5.06; 0.70 and 2.51, 1.06 about x-x and y-y respectively. Working out the points of intersection of the two ellipses by solving the equation we get, the angle $\alpha = \tan^{-1} 0.32 = 18^{\circ}$ (nearly). (See Fig. 14.)

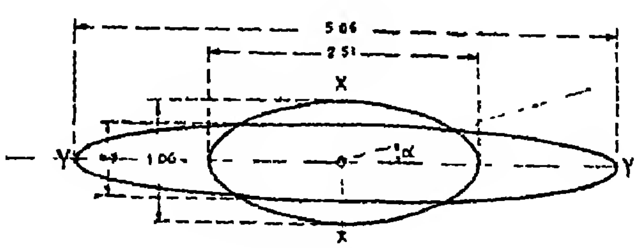


FIG. 14

In practice the angle of incidence of impact by a fast moving vehicle is not likely to exceed this. Hence a channel with its web parallel to the length of the Bridge is far stiffer and stronger for the same weight and is therefore, economical. In appearance also, the channel uprights with angle iron hand rail and flat intermediates are quite neat and good. (See Fig. 15.)

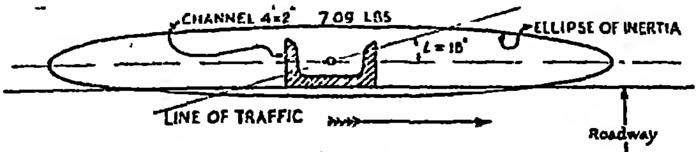


FIG. 15

As regards, Bottom Plugging I am of the opinion that a richer mix of 1 : 2 : 4 cement concrete as against 1 : 3 : 6 is more suitable as this is to be worked under water.

During the course of execution of the work, if the height of abutments is proposed to be increased to give greater water-way, the section of the abutments and wings requires alteration right from the foundation level. Sometimes a backing of boulders in addition, to relieve the earth pressure, is useful. Without these precautions, if abutments and wings are subsequently increased in height during the course of execution of work, abutments are likely to crack and give way. Where however, the sections are not altered by oversight and the bridge completed, boulder backing and staying of masonry with mild steel rods is the best recourse.

A cross section of the stream is given showing clearly the nature of the sub strata. Such a section obtained from carefully plotting the results of borings taken, is, I think, quite necessary in any scheme of bridge construction, as it clearly shows, like an X-ray photograph, the nature of the problem to be tackled. It is particularly useful where cement concrete wells are provided, which can be cast in particular lengths only and having once cast it is extremely difficult to shave off excess length. I must admit, however, that I could not understand how all the strata *e.g.*, sand, blue clay, yellow clay, etc., are each (not only the one or two upper layers) reduced in thickness in the centre of the river as compared with the banks. I request the learned writer of this paper to explain this point.

It is stated in the paper that a test load of about 48 tons was given and some small settlement was observed. I suggest the following method of Test loading. Let W be the total designed load a well has to carry at base and let A be the total area of the base of the well. The intensity of pressure on the bottom of the well will then be $\frac{W}{A}$. If a is the area of the cutting edge of the well-curb, (*See fig. 16*), the proportionate pressure taken by the cutting edge is $\frac{W}{A} \times a$ which is far less than W itself, (a being far smaller than A).

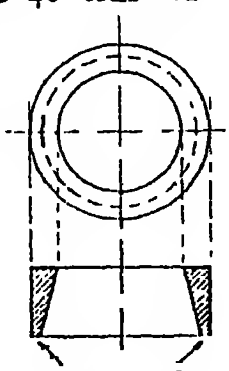


FIG. 16

Usually for purposes of test, the hollow well is loaded to 2 W. a/A (*i.e.* twice the designed intensity of loading)

and the sinking, if any, noted after about a week. This, incidentally, corrects the bottom uneven-ness of soil on account of 'draw' due to baling. A further testing by driving a crow-bar after baling out water gives entire satisfaction as to the nature of the substrata by bringing to light any sand pockets etc Heavy loading is always risky on account of danger to labour and men working on the spot and is very expensive too.

Circular wells have been provided with Reinforced concrete slab two feet thick. The distance between the centres of wells is 16 feet with a clear distance of 4 feet between their outer peripheries. I wish to know whether the slab was designed for 4 feet span or 16 feet span which is the length of the common tangent of the two outer circles of the wells. For rectangular or twin rectangular wells the span for which the slab has to be designed will only be the interval hollow and thus an economic design can be had.

Surkhi mortar is used in the construction. *Surkhi* is not a standard product and requires frequent tests In Madras, composite mortar—lime mortar with an addition of cement is generally being used against *surkhi* mortar and this is very satisfactory. Lean cement mortars (1 : 15 etc.) are also being used.

It is stated on page 20 (*d*), that staging for Reinforced Concrete work is made absolutely rigid with a high factor of safety. I wish to know what factor of safety was given and what was the calculated deflection for any particular span. It is absolutely necessary that the staging should be perfectly water-tight. Mere laying of paper does not make the staging perfectly water-tight. Moreover, paper leaves some uneven marks giving the impression of cracks. I have tried staging with zinc sheet lining. This gives a perfectly water-tight staging and a first class finished concrete surface which does not require any further touching up.

Mr. P. V. Chance (Central Provinces and Berar):—Some of the remarks I had meant to make have already been made by previous speakers and so I will not go over those points again. But there are a few points in the paper which have not been touched on.

First of all there is the somewhat curious load of a 15-ton steam roller preceded and followed by a crowd of 20 men. This is the first time I have heard of this form of loading, but apparently it is not a mistake, because it was also the test load applied to the bridge. In addition there was a test load of 100 pounds a square foot which must have produced much greater moments than the designed load.

The second point is I am not sure how impact has been allowed for. The suspended spans are easy enough but when you come to the two cantilevers and the continuous span between them, it is not clear whether you should take the cantilevers separately in which case you would get a high rate of impact of 50 or 49 per cent, or whether you should take the cantilevers and the span together I should be inclined to take the two cantilevers and the fixed span together because they form a continuous member.

Then take the test on the wells. I calculate that the bridge and the wells will weigh roughly 6,600 tons and the bridge without the wells about 4000 tons. As a very rough guess we may take the load on each well as 400 tons. Well No. 7 was tested to 22 tons and when the weight was being

taken off and there were only 3 tons remaining to be removed, it sank $4\frac{1}{2}$ feet. I admire the courage of the engineers who thought it would be sufficient to plug it with concrete. When there were only 3 tons of load the well sank $4\frac{1}{2}$ feet, and it is going to carry *400 tons*.

The third point is this. I imagine the spans are designed as T-beams though the paper does not give sufficient indication to be sure of this. That is all very well for the suspended span but when you come to the continuous span you get opposite bending moments for differents loadings. I have made some calculations, assuming that the load is the standard Indian Roads Congress load and I find that for the negative bending moment with the cantilevers loaded and the beam not loaded, the stems of the T-beams will have to be doubly reinforced with the equivalent of 16 number $1\frac{1}{4}$ inch bars top and bottom to take the negative moment. This is a very large quantity of steel and it will be difficult to get a really good concrete into the beam on account of the necessity of having an easy workable mix. I should be reluctant to use a high stress concrete in such a bridge. 750 pounds a square inch is now allowed for a 1 : 2 : 4 ordinary grade concrete according to the Indian Roads Congress apecification and I should be very reluctant to allow a higher stress and should be inclined to go below that figure.

Another point is the distribution of the load from one beam to the other by means of stiffeners. Where the loading is not uniform across the bridge it may be a considerable economy to distribute your load from one beam which is bearing the heavy load to another which is bearing the light one. But in this particular bridge, with only 3 beams and all equally loaded, I cannot see that there is any economy in transferring the load from one beam to another.

Mr. P. V. Raju (Madras) :—I should like the writer of this paper to elucidate a few points of constructional detail.

For the steining of wells, it is stated that brick-in-lime mortar with 1 lime, $\frac{1}{2}$ sand $1\frac{1}{2}$ soorki was used. I should like to know if there were any other considerations, apart from the question of cost, which made him use brick-in-lime mortar instead of reinforced concrete.

Another point is, having used brick-in-lime, what interval was allowed for the setting of the mortar between construction and sinking ? It would certainly have expedited the work if he had used Reinforced cement concrete in situ. It would also have avoided the use of bond rods and bond plates which he used in brick-work.

At page 6(d), he gives a sketch for pumping out water from the wells. A special water-proofed chamber was constructed for locating pumps. It seems to me that all this trouble could have been saved if he had used Pulsometer pumps.

Mr. G. K. Patil (Baroda State) :—This is a very interesting and instructive paper. There are certain points on which I would like to have more elucidation. One speaker has already asked as to why so very low stresses have been adopted for the concrete of beams, deck-slab etc. According to Indian Road Congress Specifications, a crushing strength of 3375 pounds per square inch is specified for ordinary 1:2:4 concrete

with 28 days curing. For the Sai Bridge, it appears that a crushing strength of 3000 pounds per square inch is specified which is rather low. The Baroda Government is constructing a Reinforced Cement Concrete Bridge over Tapti River in Navsari District, which is estimated to cost about five lakhs, and the work is now in progress. For this Bridge, river gravel is used as coarse aggregate, and we get crushing strength varying from 4,200 pounds per square inch to 5,000 pounds per square inch, for 1 : 2 : 4 concrete. I would, therefore, like to know why such a low crushing stress (*viz.*, 3000 pounds per square inch) was adopted for the Sai Bridge and what was the proportion of concrete used.

The next point on which I would like to have information, is about the thickness of brick-steining. This does not seem to have been mentioned in the Paper. What was the consideration for adopting brick-masonary for the wells and whether these wells were found to be water-tight after doing bottom plugging of 2 feet 6 inches ? Is it necessary to have the wells absolutely water-tight ? I should also like to know what purpose is served by sand-filling and whether it is assumed to act with the well. If the wells are not water-tight, I think that some of the fine sand may ooze out through the leakages and the sand filling may not serve its purpose.

Regarding the test on the foundation stratum, I would like to know what was the maximum designed load on foundations and whether the loss in weight due to buoyancy and the effect of live load and horizontal pressures due to wind and floods were taken into consideration, in calculating the same.

For Reinforced Cement Concrete wells of Tapti Bridge, 5 feet of concrete for bottom-plugging was deposited usually under 40 feet of water by means of a steel box closed at top and bottom after filling in the concrete. When the box reached the bottom, the bottom flaps were opened by releasing the catch, and it was observed that the concrete did not deposit readily, probably because it had to fall down against the hydrostatic pressure of water. As a result, some of the cement used to be washed away. In one well, after depositing 5 feet of concrete, it was observed that the level of concrete rose by about 9 inches within 24 hours. After one week the well was de-watered and an inspection of the bottom revealed that the top 9 inches layer was nothing but loose slime deposited afterwards. Therefore, in order to improve upon this method, we kept the top of the box open so as to remove the hydrostatic pressure, and this gave satisfactory results and the disturbance in concrete was minimised. However, to avoid the deposition of loose layer on top, sand filling upto 10 feet depth is being done immediately after completion of plugging. I would like to know from the author whether he could suggest any better and effective method by which concrete can be deposited under water without disturbing the cement concrete. For Tapti Bridge 1:2:4 concrete is used for plugging. For Sai Bridge I find that the bottom plugging is 2 feet 6 inches deep with 1:3:6 concrete I would like to know whether this gave water-tight bottom and whether the same is necessary.

The wearing surface provided is of 2 inch special hard wearing concrete. I would like to know from the author what he means by special hard wearing concrete, what proportion was used, and what was the nature of coarse aggregate.

Regarding the well-cap, which is shown to be 2 feet thick, I would like to know on what basis the same is designed, and whether uniform reaction from the whole section of the well was assumed or whether it was designed as a slab supported by the steining.

Mr. D. Nilsson (Bombay):—It is with great interest that I have read Dr. Korni's paper on the Sai Bridge.

This cantilever type of construction which he describes has recently become popular. Another bridge of this type was opened by the Governor of Orissa at the beginning of July last. This bridge consisted of eleven 88 feet spans with 2 end spans of 75 feet each and two end cantilevers projecting beyond the end spans of 20 feet each, giving an overall length of bridge of 1158 feet.

Dr. Korni has given a very interesting description of the sinking o the wells and he has my sympathies with his difficulties as I have found the same trouble in getting wells to sink through such unsuitable ground.

Dr. Korni has given some calculations for the strength of the steining of wells the formulas of which look somewhat queer to me but as I think Mr. Nicolaides will go into detail on the mathematics, I would only like to say that it is seldom necessary to trouble about any calculations for the design of wells except of course as regards the foundation pressure. Well steinings are normally made thick in order to get as much weight into them as possible and only a sufficiently large hole is left in the centre to deal with the plant meant to be used. Under such circumstances both the well steining and the well kerb will always be amply strong.

I agree with Dr. Korni that the design of the bearings at the cantilever ends is of great importance, and I am sure that the details he has given will be of assistance to those who would care to go more deeply into the design of such cantilever and suspended spans. Dr. Korni's paper will assist them greatly in understanding the German book called "Balkenbrucken" by Dr. W. Gehler.

It is noticed that in section 1, on the table on page 11 (d), the shear force is given as 46950 pounds or half the bearing load of 93900 pounds which is the shear at the second section. Dr. Gehler, in his example, has the same half shear at the support, but then he has a concrete hinge of appreciable bearing width and perhaps Dr. Korni can explain why he has taken the shear there as only half the reaction. I should have thought that just to the one side of the section the shear would have been the full amount of 93,900 pounds. But perhaps, the figure of 46,950 is only used for the purpose of obtaining the bending moment. In any case, the most critical section, I should think, would be the section just at the edge of the top plate of the rocker bearing, where the shear would be the full reaction of 93900. and it appears to me that the eight $1\frac{1}{4}$ inch diagonal bars are not sufficiently anchored.

Dr. Korni gives calculations for the relief given by one beam to another beam due to cross girders. This is a somewhat complicated calculation and could, I think, have been more simply done by the Theorem of Five Moments, but even that is generally quite unnecessary in this country. With the Standard Loadings, each carriage way (*i.e.*, 10 feet width) has to be loaded and may be loaded at the same time. It will, therefore,

generally be found that relief cannot be obtained for one beam from the adjacent beam owing to the fact that adjacent beam is also loaded. Relief would only occur if the one beam had a larger moment of inertia than the other and the one with the greater stiffness would of course, therefore, carry a heavier load But in the design of bridges in India, where the normal road width is 18 to 20 feet, it will generally be found that the Bending Moments in all the beams are more or less equal and it is economical to have all beams of the same size

I note with interest that cast iron rocker bearings have been successfully used, as these are of course very much cheaper than cast steel which is usually employed.

Dr. Korni has kindly given equations for calculating the most economical lengths of the cantilevers in his design for the various arrangements of spans, and these, I am sure, will be found useful. However, it is not always necessary to use exactly the spans thus found, as although the Bending Moments at the supports and the centres of the beams are not quite the same, the total steel will remain about the same and any slight extra cost in steel may be more than saved by the placing of piers in the most suitable position to reduce the cost of foundations.

I am sure we are all much obliged to Dr. Korni for his very interesting and useful paper.

E. P. Nicolaides (Bombay):—For the calculation of the external steining radius R, Dr. Korni gives the formula ·

$$R = \sqrt{\frac{6}{6-0.09\,p}}$$

with $p = \frac{5}{4}h$ as given in the paper and taking 0.09 as a numerical coeffieient, as it appears to be, the formula is not consistent from the point of view of dimensions because :

$$\frac{R}{r} = \text{number} = \sqrt{\frac{\text{tons/sq. ft.}}{\text{tons/sq. ft.}-\text{length}}}$$

On the other hand, the proof given for the value of $p = \frac{5}{4}h$ appears to contain a mathematical error. The correct equations would be :

$$P = \tfrac{1}{2}\,ph = W\frac{h^2}{2} + \left(\frac{E-W}{2}\right) h^2 \tan^2\left(45 - \frac{\theta}{2}\right)$$

$$= W\frac{h^2}{2}(1 + \tan^2 27^\circ) = \frac{5}{8}Wh$$

$$\therefore\quad p = \frac{5}{4}\,Wh$$

against $p = \frac{5}{4}h$ given in the paper.

Now take a well with internal radius $r = 4$ feet.

depth $h = 30$ feet.

W = weight of water per cubic foot = 62.5 pounds = 0.0279 tons.

Then Dr. Korni's formula would give :

$$R = 4\sqrt{\frac{6}{6-0.09\times\frac{5}{4}\times0.0279\times30}} = 403 \text{ feet}$$

i.,e. the required thickness of steining would be 0.03 feet = .4 inch which is absurd.

An adequate formula for the calculation of R is given by the Theory of Elasticity in the analysis of stresses and strains of a circular pipe of appreciable thickness compared to its radius and subjected to a uniform pressure all round on the outside face. This formula, applied to the well considered above, would give a thickness of steining of 1 foot.

Although adequate from the point of view of strength, this steining thickness would not make the well heavy enough for sinking in most cases.

Dr. Korni gives the maximum moment in an oblong well = $\frac{5}{48}$ hL^2 which is, again inconsistent from the point of view of dimensions. From this formula it would appear that a bending moment is expressed in cubic feet or more generally as a length raised to the third power.

Assuming the long wall of the steining as fixed at the ends, a correct expression for the maximum value of the Bending Moment would be $\frac{1}{12}$ pL^2 where $p = \frac{5}{4}$ wh as ascertained above.

Then Bending Moment = $\frac{5}{48}$ whL^2 and is readily expressed in foot pounds per foot or any other similar units as selected.

In the same way the correct expression for the maximum stress in the steining would be :

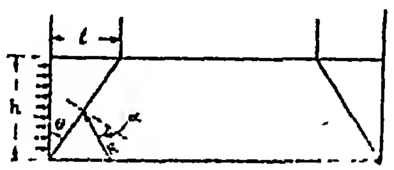
$$f_t = \frac{5}{8} \times \frac{whL^2}{t^2}$$

expressed in pounds per square foot or similar units.

For the calculation of the dimensions of the kerb, Dr. Korni sets forth a principle, *viz.* that the effect of total strains in the kerb produced by a variable bending moment along the axis xy must be zero.

In his calculations, however, he estimates only the overturning moment of the forces acting on the kerb about the centre of its base and goes no further. For what purpose is this overturning moment calculated and how can it be connected to the principle set forth at the beginning ?

If it is at all necessary to calculate the dimensions of the kerb and more particularly, the cutting angle *θ*, the only condition we can set forth is that this angle *θ* must be such as to render the resistance to sinking a minimum. To satisfy this condition we can reason as follows :

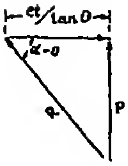


During the sinking of the well the resistance against the kerb consists of:—

(*a*) a uniform earth pressure 'e' acting on the external face of the kerb and which may be taken as normal to the surface (skin friction neglected). The total of this pressure over the height h of the kerb is $eh = \frac{et}{\tan\theta}$

(*b*) a total passive earth pressure R on the sloping face of the kerb which may be taken as acting at an angle α to the normal on this face in order to include for friction.

The total vertical resistance to sinking is the resultant of the above two forces and according to the diagram of forces is equal to



$P = \frac{et}{\tan\theta}\tan(\alpha+\theta)$, α being the known angle of friction. The only variable is θ and to make P minimum we must have

$$\frac{dP}{d\theta} = 0$$

i.e., $$\frac{\tan\theta\,[1+\tan^2(\alpha+\theta)] - \tan(\alpha+\theta)\,[1+\tan^2\theta]}{\tan^2\theta} = 0$$

which, after simplification, gives

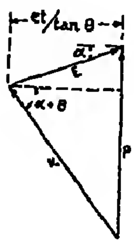
$$\tan\theta\tan(\alpha+\theta) = 1 \qquad i.e.\ \theta = \frac{\pi}{4} - \frac{\alpha}{2},$$

For $\alpha = 20^\circ$ $\theta = 45^\circ - 10^\circ = 35^\circ$ and $h = 1.43\ t$

$\alpha = 30^\circ$ $\theta = 45^\circ - 15^\circ = 30^\circ$ and $h = 1.73\ t$

It will be seen that even for the small angle of friction of 20 degrees, the inclined face of the kerb must have a slope of $1 \cdot 1\frac{1}{2}$ giving a pointed end which may be too thin for practical purposes.

If, on the other hand, we take into account the skin friction on the outside face of the kerb also, then the pressure E on this face will act also at an angle α to the horizontal and the resultant total reaction P can be found from the attached diagram of forces.



$$P = \left(\frac{et}{\tan\theta}\right)\tan\alpha + \frac{et}{\tan\theta}\tan(\alpha+\theta).$$

Here, again α is the known angle of friction, and the only variable is θ. Therefore, the minimum P will be given when θ satisfies the equation

$$\frac{dP}{d\theta} = 0$$

The solution of this equation is rather long, but the final relation obtained is

$$2 + \tan^2\theta - \tan^2\theta\tan^2(\alpha+\theta) = 0$$

and gives for

$\alpha = 20^\circ$ $\theta = 42^\circ$ or $h = 1.11\ t$

$\alpha = 30^\circ$ $\theta = 32^\circ$ or $h = 1.60\ t$

With the greater angle θ obtained thus, the cutting edge becomes stronger and the values given for h correspond quite well to what is usually adopted in practice.

Dr. M. A. Korni (Author) :—I am very thankful to the members of the Congress for the good reception they have given to my paper and for valuable comments. I was so much absorbed in the criticism that I omitted taking notes and, therefore, find it rather difficult to give adequate replies to the comments. Moreover, as the time at our disposal is very limited, I have been advised to reply to the comments in writing. I shall accordingly make replies by correspondence.

Rai Bahadur S. N. Bhaduri (Chairman) :—We must thank Dr. Korni for his able paper. The discussion was long, and we are hard up for time. He has promised to give us replies in writing to the points raised. The Secretary shall send him a copy of the comments made by the members.

CORRESPONDENCE.

Reply of Dr. M. A. Korni, (Author), to the Comments.

Mr. S. B. Joshi finds fault with my treatment and analysis of the re-entrant angle in the cantilever. In order to prove that my analysis is wrong, he narrates the assumptions made in developing the theory of elastic bending and recalls to memory the stresses and deflections in beams in simple bending, the uniformity of curvature neutral axis; etc., just as they are found in elementary books on strength of materials and theory of structures which do not give an advanced treatment of the subject.

The phenomena of stresses in the re-entrant angle are, to put it plainly, due to the difference in mass distribution. I will try to explain how this conclusion has been arrived at.

As far back as prior to the Great War of 1914-1918, it was observed that Letter shaped* structures did not show failure in the places where failures should have been expected on the theory developed in dealing with simple structures. The strengthening of or improvements made in these structures in accordance with the elementary knowledge of resistanee of materials, therefore, were of no use in such cases.

The phenomena of 'strange' stresses in Letter shaped rigid structures, like those shown in Fig. 17 (below) were investigated by some great scientists including Professors Dr. Foppl, Dr. Ing. Bernhard, H. C. Von Widdern, and L. Kettenacker.

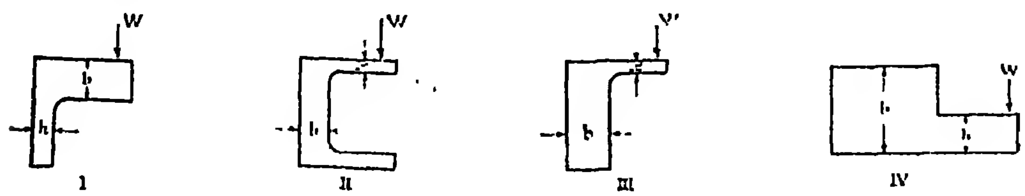


FIG.

They set before themselves the problem of tracing the distribution of stresses in such structures under load and using an optical polarisation method to achieve this end. The method was based on the principle of

* Rigidly connected structures having axes in different planes.

refraction of light. When a ray of light passes through a transparent object, like glass or celluloid, the refraction that takes place is 'single.' When, however, the same object is loaded, and therefore in a condition of stress from point to point, the refraction of the same ray of light in passing through it, is 'doubled' in the area effected by the stress.

Further researches were made by means of the polarisation method using the Nicol's prism. Models of different shapes made of a transparent material were subjected, under stresses, to the polarisation method and the distribution of stresses was traced.

The cantilever end belongs to the family of Letter shaped structures investigated as mentioned above. The sketch (fig. 18) represents the trajectory of principal stresses in a Letter shaped object of the following dimensions:—

$$\frac{b}{h} = 2, \quad \frac{r}{h} = 1 \quad \text{and} \quad p = \frac{16}{3} h.$$

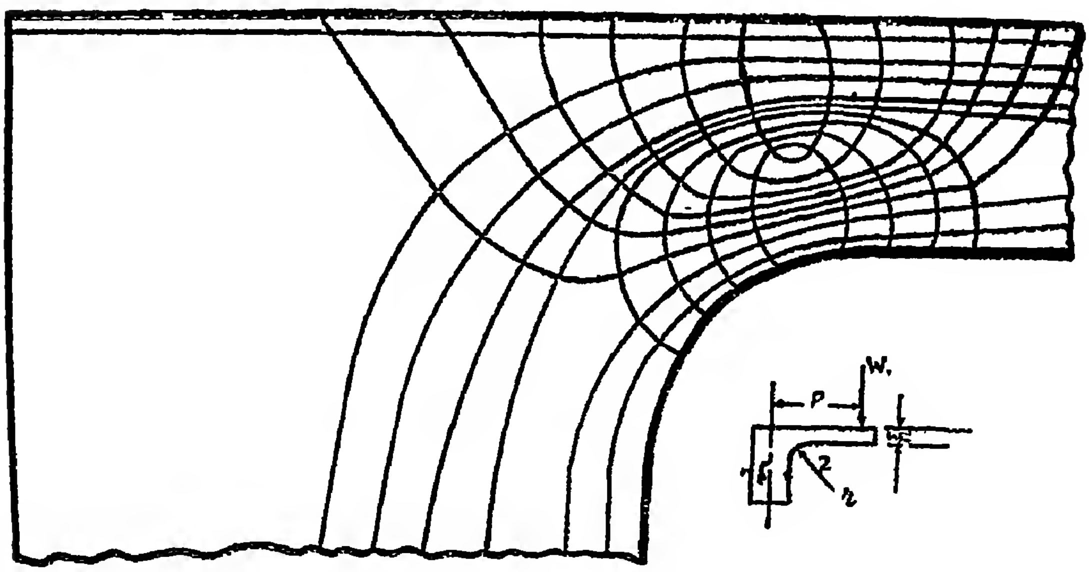


FIG. 18—Trajectory of Stresses.

The distribution of stresses, it would appear, is quite different from what would ordinarily be expected. (Also see Fig. 19). It is not that the theory of elastic bending does not apply to these cases but the application is made in accordance with the trajectory of stresses obtained by the polarisation method.

FIG. 19

Photo-elastic method (by use of polaroid) for stress analysis in a re-entrant angle of a cantilever end such as fig. 17 (iv).

I will illustrate how the bending moment in section I, *vide* footnote on page 11 (*d*), is due to expansion and contraction.

FIG. 20

If the cantilever carries the load W (Figure 20) due to central slung span at a distance 'a' from the re-entrant angle, the Bending Moment will be W.a. If, however, due to expansion, it has moved a distance x, the Bending Moment will be increased to W (a+x) (see figure 20). The rocker as shown in the sketch (Fig. 21) concentrates the load "W" at one point, but the reaction on the plate is $\frac{W}{2}$ to the right and another $\frac{W}{2}$ to the left of the vertical line drawn through the point of concentration of the load.

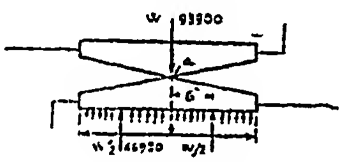


FIG. 21

The Bending Moment in section I is thus easily seen to be 46950×6 = 281700 inch pounds.

With regard to both positive and negative signs appearing before the value of the Bending Moment in the centre of span Bm_1, *vide* table on page 9 (*d*), the reason could be easily understood on a reference to the influence lines of the Gerber Bridges. The following diagrams (figure 22) illustrate my point.

FIG. 22

If the load is placed on the cantilevers, the Bending Moment in the middle will be negative, while if the load is placed in the centre, the Bending Moment will be positive. The beam is accordingly reinforced to take both these Bending Moments.

Nothing was said as to taking or not taking the horizontal pressure in designing the reinforced concrete well curbs, but, as a matter of fact, the pressure P is shown in the diagram on page 5 (*d*) as a working force in the opposite direction and, therefore, assumed as a necessary item without which the equilibrium of forces could not established. During the time of water jetting P is freed, but when jetting of water is ended, it is re-established. Therefore, these two conditions have to be considered and curb designed with P and without as the worst case may be.

As regards the preference given to the circular wells in the Sai Bridge over the rectangular wells, it might interest Mr. Joshi to learn

that square wells are being sunk by one of the Public Works Department Engineers on a ghat of Benares which is at present, under repairs

Mr. Joshi's guesswork based on the information collected by him from the Molesworth's handbook for the derivation of the formulae quoted by me for determining the thickness of well-steining is wrong. He would have done well in looking up papers* written on the subject by Massotte, published in T. de Travaux 1932 or reading Sangler on 'The supporting strength of Rigid Culverts' or Ch. Duloch Curral.

Mr. Joshi's remark that $\frac{Bm}{Z}$ = stress cannot be used in random sections is not understood. Suppose for a Moment a frame, is loaded with a weight W as shown in the sketch. He means that $\frac{Bm}{Z}$ = stress cannot be applied to the beam as well as to the columns. In any way

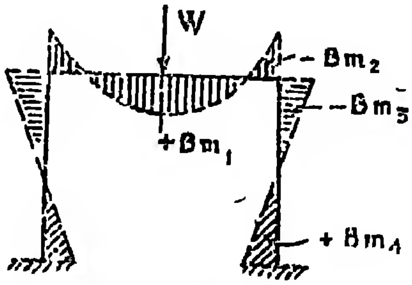


FIG. 23

$\frac{Bm}{Z}$ can be applied as long as there is a Bm and a Z (the modulus of the section) in existence. His calculations for finding mathematically the worst section are a waste of effort, as the results obtained from the polarisation method do not tally with it. The polarisation method has proved that worst section has very much to do with the sudden change in sectional areas at the end of the cantilever

With regard to Mr. Joshi's objection to p = $\frac{3}{4}$ h, I would say that P is a pressure and measured in tons I will explain this when I come to answer Mr. Nicolaides' comments

As regards the objection to the word "Elastic Prop" being used, I do not think it is worth going into a long discussion over it as there is very little practical interest in it But concerning the disagreement with the fact that the strata of *kankar* was thinned out in the middle of the river, because it does not conform to the commentator's theory, I beg to state that borings were taken in conjunction with the Public Works Department on two occasions and checked by the Executive Engineer of the Department. This reminds me of a story about a villager who visited a town for the first time in his life and like all his kind, he found his way to the zoo soon after his arrival. He was immensely intrigued on seeing the monkeys and lions and tigers, all old acquaintances of his boyhood days when his father had told him stirring stories of wild animals. But, for some unknown reason, the giraffe had not figured in these old tales and now when the villager saw the strange and lofty creature for the first time, he exclaimed · "I don't believe it !"

In specifying stresses, the strength of the available aggregate must be considered too. If the breaking stress in stone chips is about 2500 pounds per square inch, the stress in concrete cannot be allowed to be more than 1200 pounds per square inch. In the case of the Sai Bridge, the reinforced concrete slab on the top of the piers was subjected to a

* *Vide* Annex page 75 (*d*)

very low pressure due to a dispersed load over a large surface area. The compressive stress was about 250 pounds per square inch. A stronger concrete would have only meant a waste of money and materials.

I thank Mr. Joshi for his very interesting comments which have converted this paper on a very dry subject into a vivacious debate.

Mr. Murrell thinks that clay and *kankar* do not provide sufficiently stable ground for a Gerber Bridge and cites two cases where the piers were founded on soft rock or soft sand-stone and took a tilt on the upstream side. Mr. Murrell says it was fortunate that the superstructure was of steel. I suggest that it would be still more fortunate to have wooden superstructure in such cases, as this would be easier to lift.

One of these two cases is within my knowledge. It is a railway bridge over the Amanat river near Daltongunge. The soft rock has a 50 feet thick covering of well protected coarse sand. This layer of sand remains undisturbed. The pressure on the soil according to the records of the East Indian Railway is 3 tons per square foot. This pressure, you will agree, is very reasonable, if not low, for soft rock. The failure of the bridge was not due so much to the soil being bad as to inferior materials being used in the piers and wells. There might on the other hand, have been a thin stratum of soft rock left after the process of mining on which the bridge pier rested. The vicinity is full of coal mines and there is a suspicion that an old abandoned coal mine exists on the site. This bridge is still causing anxiety.

Exceptional cases like this bridge cannot be taken as a rule and it cannot be reasonably inferred from these that clay and *kankar* are bad bearing strata. The world experience in soil mechanics based on fundamental research also points in the opposite direction. A study of the research reports* on clay by H. S. Housel, Professor of Civil Engineering, University of Michigan will be relevant to the subject and is suggested. As far as my experience goes, several bridges of Gerber type have been built on ground which is far from rocky and are still standing although it is more than ten years now since they were erected. Besides, the worst ground can be improved to such an extent that this type of bridge can be safely built and used, I do not see any reason for the rigid rule brought forward by Mr. Murrell that cantilever bridges should be built on rocky foundations and only a free span bridge should be allowed on a ground other than rock. We all know that more free span bridges of steel have failed in India than of concrete, which are mostly of a continuous type, and all the failures were due to something other than the soil condition, most of them being washed away by floods.

If Mr. Murrell's contention is accepted, I am afraid, reinforced concrete bridges of any type or system will be unable to find a footing in India. Concrete bridges stand earthquakes best and take up torsion without getting twisted to the same extent as steel. Mr. Murrell is unduly terror-stricken as cases of tilted piers are few and far between, and piers can, with due precautions, always be made stable.

* *Vide* Annex page 75(*d*)

Investigations ought to be undertaken to ascertain if link suspensions in Gerber bridges effect any economy. I promise doing so at the first opportunity that is offered to me.

Ragging out the cantilevers into the banks is generally unacceptable to the authorities. They prefer to protect the banks from scour by means of having abutments. Imagine, for example, a bridge over the Ganges with banks of cultivated earth, having no abutments. At flood time, when bridges are most needed, there is a great danger of the connection between the bridge and its approach being washed away. The suggestion of Mr. Murrell is certainly good for rocky or well-protected embankments.

Mr. Murrell's impression of contractors having been given sketches of a bearing never yet used, is based on some misunderstanding. The contractors had themselves come forward with the proposal of putting rockers into the end cantilevers. These rockers were used by the contractors previously in Teesta bridge approaches in 1931.

There is a greater reaction in the Sai Bridge than was the case with Auranga bridge. Load dispersion over a greater area was, therefore, necessary and ½" plates below the sliding rocker were used.

Auranga cantilever end was also splayed out from 15 to 22 inches and had no straight sides to the web. This is necessary to provide against the heavy shearing forces.

The cross beams or stiffeners add to the rigidity of the structure which is the most important and striking feature in reinforced concrete structures. I cannot give a better argument in support of this view than to suggest that stresses developed with and without the stiffeners may be computed and compared.

Steel forms, I agree, are to be preferred. They are in general use in England and on the continent where they are available with special firms on loan. In India, where bridge-building is so rare, the contractors so many, and the engineers are all panic-stricken on seeing a crack in concrete, steel forms are very costly to provide and are, more or less, out of question

I take this opportunity to thank Mr. Murrell for his kind remarks that the test results of the Auranga Bridge were excellent, and although the bridge was built on similar soil to that of the Amanat Bridge, I assure him that the piers of the bridge will not tilt, and if they do, the bad mess that he so vividly described in the beginning of his comments, can be remedied, quite as easily as in the case of steel structures.

Mr. S A. Shareef has made the hydraulic characteristics of the vicinity of the bridge his object of criticism and the reason for this is the high velocity under the bridge which he has calculated to be 20.1 feet per second. The calculation he has made is simple—he divided 181,800 cusecs by 9042 and got 20 1 and he is correct But he misunderstood the description of the characteristics. The maximum flood discharge is 1,81,800 cusecs and the catchment area is 4272 square miles. From the site plan (opposite) it is to be seen that in this area there are three big channels for draining the floods—the Gomti river, the Sai river and another river bed passing by Azamgarh Parallel to the Sai river is the mighty Ganges. Therefore 1,81,800 cusecs are divided between these

rivers. The velocity on the site of the bridge during the highest flood level was carefully measured and found to be 4.8 feet per second, [*vide* page 3 (*d*)]. Therefore the cubic contents of water passing, not taking into account any friction, etc. amounts to 9042 × 4.8 = 43,400 cusecs, and the rest about 1,38, 400 cusecs is taken over by the other channels. In the same page of the paper the author describes his anxiety when he found that in 1936 the flood exceeded the previous high flood by 1.11 feet. He put up the question of raising the bridge by 2 feet, but the authorities found it unnecessary as they were probably satisfied as a result of having checked the records of flood levels.

SKETCH PLAN OF CATCHMENT AREA

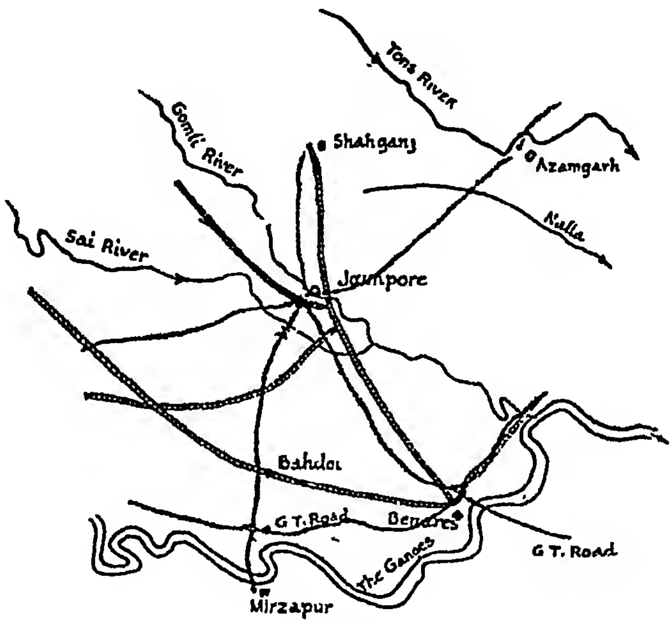


FIG. 24

The formulae for calculating the discharge of catchment areas are many and they are all approximate. I assume that the Public Works Department in the United Provinces have used Colonel Dickens' formula.

Mr. Shareef may with full justification put the question: "Why did the author mention the catchment area in thousands of miles instead of the catchment area in square miles actually discharging through the bridge. The reason for this is that this catchment area was given by the Government authorities, which rather frightened the author when he started to design the bridge, but taking the measurements of the velocity in high flood he found that the maximum discharge differed from the amount given.

I wonder how Mr. Shareef found the value of shear per square foot to be 86.5 pounds. The area of dispersion is so great that the shear stresses are practically negligible in slabs. Even in the British Standard Specification, known to be very conservative, they do not ask for a computation

of shear in slabs. Slabs, when tested to destruction, have never been found to fail in shear.

The slab has not been designed in accordance with Mr. Brijmohan Lal's theory. Mr. Shareef is referred to the researches on slab design carried out by some of the most prominent scientists and engineers such as Professor Bach, Dr. Marcus, Pigeaud, Professor Calerkin, Dr. Fopple, etc. My paper entitled "Methods of economical Deck-slab designs" read at the Institution of Engineers (India) may be referred to. Slabs of 9-inch thickness 20 feet by 20 feet, supported on all sides, covered with 3-inch rich cement concrete laid on 1-inch sand, and carrying a live load of 12-ton wheels (contact area 24 inches by 4 inches) are in existence and show no weakness. The necessity of the longitudinal bars is also explained in this paper of mine. Mr. Shareef will find the reasons in W. L. Scott's book "Reinforced Concrete Bridges", also.

The wearing coat is simply there to protect the slab. It could be repaired when worn out. A 3-inch coat will wear just the same on the surface as a 2-inch coat and the sooner the wearing coat is replaced the better. A thicker wearing coat will make the bridge heavier and un-economical and is not advocated.

I have explained the question about inclined sections *vide* my reply to Mr. Joshi's comments which may be referred to.

Mr. N. Durrani recommend shaving handrails 4″×2″ at 7.09 pounds instead of 3.5″×2 5″ at 7.17 pounds. Although the difference is not much, the author is willing to consider it and make use of it, if the cost is not exceedingly high. The railings designed by the author for other bridges have been in existence for over fifteen years and no complaints have been made against them as yet. The author is always ready and willing to learn of other engineers' experiences.

Plugging with cement concrete 1:3 6 was adopted by the Public Works Department. A richer proportion would have meant an increase in cost. The laying of the concrete in deep water without loosing the cement much can be done by two methods :—

1 The mixture should be prepared dry-wet and at the time when the cementing process has started, it should be lowered down in a closed bucket with a detachable bottom plate. The cement in this case sticks to the aggregate

2 Another method is to prepare the cement concrete dry-wet, and fill the mixture loosely into gunny bags. The bags are gently lowered by means of the buckets mentioned before. Through the weight and pressure between the bags, the cement is squeezed to a certain extent and the layers become monolithic. The bags must be thin and their weaving of as large a mesh as possible.

The question concerning the geological condition of the river bed, has already been answered. The deterioration of the *kankar* strata in the middle of the river is a problem for a geologist to solve. The author's intention in writing his paper was to deal with the construction of the Sai Bridge and for the purpose of making records, he has given all phenomena and facts met with at the time of construction.

The author does not see the point why 48 tons is a big testing load. It is much less than 300 tons which would be required when the piers had been completed. The steelplate at the bottom of the well was 16 square feet, and 3 tons per square foot of bearing capacity was assumed and therefore the 48 tons mentioned. The problem was to find whether 3 tons per square foot, not near or beside the well, but of the actual ground covered by the well, was sufficient, and this the author thinks is the cheapest and best method. Mr. Durrani is anxious to know what distance from centre to centre the author has adopted for the slab. From the drawings it will be seen that the wells are spaced 4 feet apart and the diameter of the wells is 12 feet. The distance between the centres of the wells is 16 feet. As regards the span of the slab, it should be made according to the Indian Roads Congress Standard Specification and Codes of Practice for Road Bridges in India, D22, (See page 102). It reads thus: "The effective span of a slab shall be taken as the distance between the main vertical sides of the supporting members plus the effective depth of the slab at the support, or the span between the centres of the necessary bearing surface, whichever is less"

On the Continent, the following rules are observed which can be seen from the sketch of a general example given below.

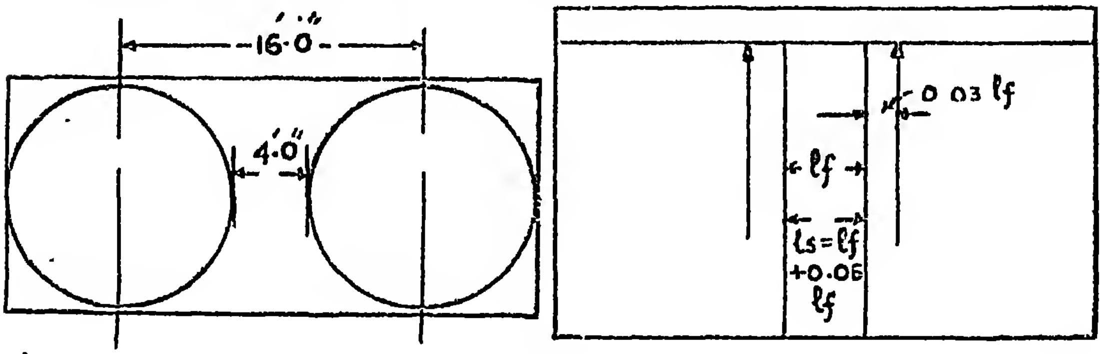


Fig 25

The average span of the slab

$$= \frac{(16 + 0.06 \times 16) + (4 + 0.06 \times 4)}{2} = 10.60$$

and not 16 or 12 as assumed by the commentator. As regards the best shape of wells suitable for sinking in India, I would recommend the commentator to read the excellent paper on 'Bridge Construction with particular reference to Foundation in Indian Conditions', by C. I. Stabler in the Journal of the Institution of Engineers, (India) Vol. XI, 1932.

The author is quite puzzled as to why Mr. Chance thinks that a load consisting of a 15-ton steam roller, preceded and followed immediately by 20 men—for which the bridge was designed and tested—is curious and surprised that it is the first time he has ever heard of this form of load. There is more sense in this load than in the imaginary knife edge load of 6 or 9 tons with an impact, which can only be compared to a bomb without explosives, pointed at one end and dropped from a height causing an impact according to the formula — $I = \frac{1}{2} \cdot \frac{65}{45 + L\frac{(n+1)}{2}}$

which will cause destruction as no slab or beam will be able to withstand it.

Representation of a Knife Edge Load

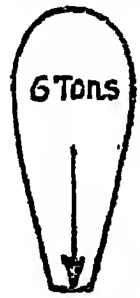


FIG. 26

In isolated places like the site of the Sai Bridge, it is quite possible and logical that a 15-ton steam roller required for road making may pass the bridge. Twenty coolies following the steam roller is quite sensible too. This gives us the maximum load on a bridge like this and there is nothing funny about it. Most of the road bridges in the world are designed for steam rollers followed by a crowd. The fact that Mr. Chance has never heard of it is rather surprising.

Mr. Chance is anxious to know whether impact has been taken into account. I can assure him that it has been. The loading and impact has been formulated by the Public Works Department of the United Provinces and accordingly an increase in loading of 25 per cent has been used for the continuous beam and cantilever.

Mr. Chance, has roughly calculated the weight on the wells to be 4000 tons. Assuming this figure to be correct, although it is a bit exaggerated, the weight on each well will be $\frac{4000}{16 \text{ wells}}$ = say about 250 tons, and assuming that 6600 is the correct figure for total weight, then the weight of the wells will be $6600-4000=2600$ tons. Then according to his own figures, the weight of each well will be $\frac{2600}{16} = 163$ tons, and not 400 as he stated. Apparently he means that 400 tons is the weight of superstructure and piers together.

The area of each well of 12 feet diameter is 113 square feet. The pressure on the soil will be $\frac{163+250}{113}=3.6$ tons. When calculated exactly, it will be found to be about 2.5 tons only, but even 3 6 tons pressure per square foot on kankar is very reasonable. As the author described in his paper, the bearing capacity of the soil-and not of the wells-was tested, and it was found in time that in this well (Well No. 7) the soil was defective, so it was improved. It may interest Mr. Chance to know that the bridge was loaded with the full 400 tons (after his calculations), plus live load and I must add that the bridge is now in the third year of its existence. It is not the courage of the engineer but his sound way of tackling difficult bridge problems economically that is to be admired, as no guess work was used.

About the third point of Mr Chance, where he has criticised the design of a T-beam, there is nothing funny about this either. The Negative Bending is well taken care of by steel reinforcements.

As regards getting good concrete in beams, there is nothing to be afraid of. An engineer who has long and successful experience of reinforced concrete is quite capable of making a good job.

If a mixture of 1:2:4 produces a breaking stress of 3000 pounds per square inch, 750 pounds per square inch renders a factor of safety of $3000 \div 750 = 4$ which is quite safe. The test results have proved it. The bridge was so rigidly built that under the specified test load no deflection was observed. After all, the deflection is *the* criterion of the quality and the safety of a bridge.

In reply to Mr. P. V. Raju, I would say that, as previously explained, brick-in-lime was used for the only reason that lime is found on the spot and brick is very cheap. Reinforced concrete piers would have been very costly. The price of bond plates and bond rods is negligible while reinforced concrete in the vicinity of the Sai Bridge is very expensive, as good sand and stone chips have to be imported from elsewhere. A pulsometer is not always suitable as it takes up a lot of space and fills the well with steam, making it difficult for the labourers to work inside. Moreover, a pulsometer was not available and it meant waiting a long time for one to be brought.

Mr. G. K. Patil wants to know why such a low crushing stress was adopted. The author has already explained why crushing strength of 3000 pounds was specified. With the aggregate found there a better concrete could not be obtained. As regards the thickness of steining, Mr. Patil can now calculate that for himself with the help of the author's formula given on page 4(*d*).

It is difficult to obtain an absolute water tight plugging and it is not essential. The pressure being 2.5 tons per square foot, it produces a compressive stress of about 40 pounds per square inch only and any concrete, even with big honeycombs, will be able to resist this. Completing the filling with loose sand, the honeycombs are closed. The maximum load on foundations was 2.5 tons per square foot and the buoyancy was not taken into consideration for the purpose of calculating the soil pressure.

Mr. D. Nilsson has shared the work of criticism with Mr. Nicolaides and while Mr. Nilsson has taken the sympathetic part, Mr. Nicolaides has taken it upon himself to provide the necessary weight. Being a joint comment, the author takes the opportunity of giving a common reply which will save him time. Messrs. Nilsson and Nicolaides could not understand how the shear in section 1 works out to 46950 pounds. This is explained in my reply to Mr. Joshi.

Mr. Nilsson thinks it is not necessay to calculate the steining of a well as it can be done by guesswork and that the formula attached looks queer to him which Mr. Nicolaides is going to prove. In doing so Mr. Nicolaides has reconstructed the formula and made a mess of it. I dare say he has succeeded but he did not convince me.

Take the formula $R = r\sqrt{\dfrac{6 \text{ tons}}{6 \text{ tons} - 0.09p \text{ tons}}}$. '$p$' denotes the water pressure in tons [see author's paper, page 4 (*d*)]. As the values under the root are in tons, the water pressure and the earth

pressure are taken in tons and as the ratio of the specific gravity of water and sand is 1 : 2, therefore as unit take W = 1 ton and E=2. tons. The total active combined pressure is :

$$P = \frac{Wh^2}{2} + \frac{(E-W)}{2}h^2 \times \tan^2\left(45^\circ - \frac{\theta}{2}\right)$$

$$= \frac{5}{8}h^2 \text{ tons} = \frac{ph}{2},$$

therefore $p = \frac{5}{4}$ h tons, and the formula $R = r\sqrt{\frac{6 \text{ tons}}{6 \text{ tons} - 0.09 \text{ p tons}}}$ is quite correct.

As Mr. Nicolaides cannot follow this simple algebraic formula showing how to account for W (water in tons) and E (earth in tons) we will work it out for him in pounds. Let us assume that

one cubic foot of water W = 62.5 pounds,

and one cubic foot of earth E = 125 pounds, as on page 4 (*d*).

Substituting these values in the equation,

$$P = \frac{Wh^2}{2} + \frac{(E-W)h^2}{2} \times \tan^2\left(45^\circ - \frac{\theta}{2}\right)$$

we get,

$$P = \frac{62.5h^2}{2} + (125-62.5)h^2 \times \tan^2 27 \text{ degrees}$$

$$= 31.25h^2 + 31.25h^2 \times 0.25$$

$$= 39.05\ h^2, \text{ in lbs.}$$

Converting it into tons, we get,

$$P = \frac{39.05\ h^2}{2240} \times 35.8^* \text{ tons.}$$

$$= 0.625h \text{ tons.}$$

$$= \tfrac{5}{8}h^2 \text{ tons.}$$

$$\text{But } P = \tfrac{1}{2}ph,$$

$$\therefore \tfrac{5}{8}h^2 = \tfrac{1}{2}ph,$$

$$\therefore \quad p = \tfrac{5}{4}h \text{ where } h = 30 \text{ feet.}$$

$\therefore \quad p = \frac{5}{4} \times 30$ tons, and not $\frac{5}{4} \times 0.0279 \times 30$, as Mr. Nicolaides takes it to be [*vide* page 52 (*d*)].

Now that I have converted the tons into pounds to suit Mr. Nicolaides, I hope he will unbend towards the formula and that Mr. Nilsson will not think it so queer. The formulae for the oblong wells are based on the same principle, so they should be understood now without and further explanation.

Mr. Nicolaides seems to have taken a great dislike to the statical equation for calculating the dimensions of the kerb and Mr. Nilsson thinks that this can be done by guess work. Mr. Nicolaides has used this *formula* on one particular occasion, namely for the angle θ and by solving numerous

* 1 ton of Water = 2240 lbs ÷ 62.5 = 35.8 c. ft.

other equations has come to the conclusion that the greater the angle, the stronger are the cutting edges. This is a very strange conclusion at which to arrive. If the angle of the cutting edges grows bigger, up to say 90 degrees then no cutting edges will be left in the kerb. I do not think it is worth while going into a debate over this question, but instead I will give a numerical example of a complicated kerb which was successfully built.

Drawing on page 68 (*d*) represents a railway bridge where extension necessitated the increase of the piers and abutments. For this reason the wells were designed in such a way as to have great bearing area and a light pier, which is the correct way to do it and not as Mr. Nilsson thinks that for the sake of sinking wells easily they should be made as heavy as possible. This increases the soil pressure unnecessarily and it is a bad practice for a bridge builder. The extended portion of the bridge is clearly shown in drawing figure 27.

Drawings on page 69 (*d*), show the plan of the kerb and the section of a pier standing on the well.

In the drawing on page 70 (*d*), the force distribution is shown and it is this drawing that we are going to analyse. From drawing No. 2, which shows the arrangement of the reinforcements, it will be realised that this type of work cannot be done by mere guess work.

To spare ourselves from ponderous figures running into 8 digits, we will take forces in tons and linear distances in yards instead of feet.

The following working stresses are taken,

For concrete in compression	675 lbs. per sq. inch.
Steel in tension	18000 lbs. per sq. inch
Angle of repose of earth above water level	$\theta = 37^\circ$.
Angle of repose of earth in water ..	$\theta' = 25^\circ$.

$$\tan^2\left(45^\circ - \frac{\theta}{2}\right) = 0.25 = a.$$

$$\tan^2\left(45^\circ - \frac{\theta'}{2}\right) = 0.406 = a'.$$

PIERS & ABUTMENTS EXTENSION FOR A RAILWAY BRIDGE OVER THE RIVER RHEIN

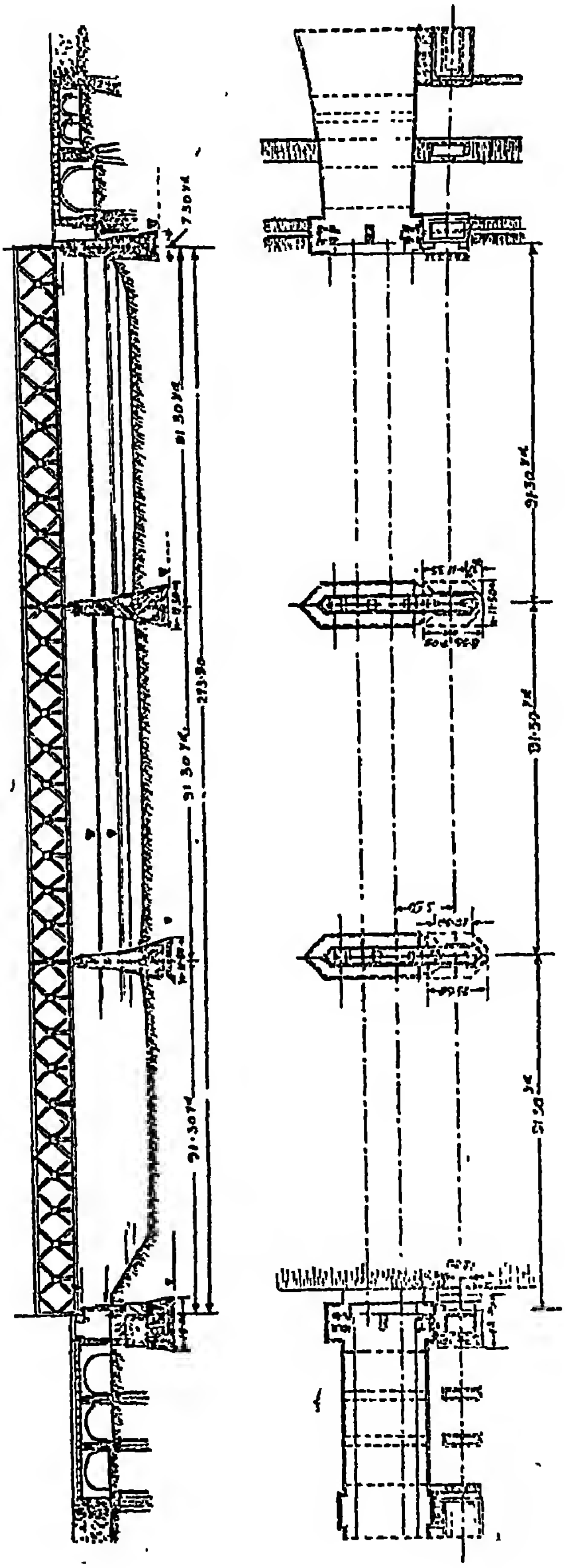


FIG. 27

Earth pressure $E = \frac{1}{2}\, g\, h^2\, a'$-in tons and yards.

Earth pressure triangle $p = g\, h\, a$ in tons and yards.

Friction on the walls $R = \eta E = 0.5E$.

Horizontal force H on the kerb is acting on 45° inclined surface. (fig. 3/3—a)

The vertical forces $V_1 : V_2 = f \times 4.75 : f \times \frac{15.8}{2}$

$$\text{or } V_1 = 3/5 \times V_2 = 0.6V_2.$$

As $V_1 + V_2 = A$; therefore $V_1 = A - V$.

$$A - V_2 = 0.6V_2$$

$$V_2 = \frac{A}{1.6} = 0.625\ A$$

$$V_1 = A - V_2 = 0.375\ A.$$

The friction angle between cement concrete and earth $\theta' = 25^\circ$ and according to the triangularity of forces (see fig. 31) where,

$a = 45^\circ - \theta' = 20^\circ$.

$H = V_2 \tan a = 0.625A \times 0.364 = 0{\cdot}23A$

To calculate the longitudinal reinforcement of outer wall (knife edge wall), the following conditions causing the maximum Bending Moments in the vertical direction have to be considered, The conditions are; To assume that the kerb is cast, placed and supported on the five edges as in the sketch. This condition we may call load condition No. 1.

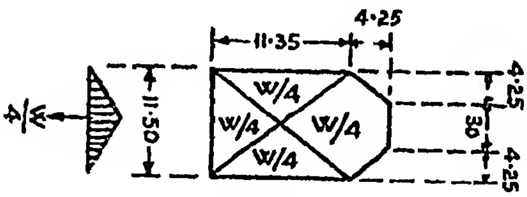


FIG. 34

For calculating the deck reinforcement, the stirrup on which the deck is suspended and the transversal ribs, a second condition has to be investigated which we may classify as load condition No. 2.

This case is characterised by forces causing maximum stresses in the above mentioned members of the kerb, when the same is sunk down to its upper edge. The flood being low, there is no compressed air in the working camera and the room between the walls is filled with light concrete. The wells are sunk with the help of an air chamber (See fig. 1/3 table 3.)

A third condition which is necessary to be investigated for the calculation of reinforcement for the transversal walls (deck supports) and the cantilevered out reinforcements on which the work camera walls are built, is obtained when the kerb is sunk down to the bottom, the flood level is low and there is absence of air in the labour room.

LOAD CONDITION No. 1.

The caisson is on R. L. +269.61

Weight of the caisson W_c=1200 tons and it is distributed between the four walls.

Bending moment of a wall is :

$$\text{Bm Max.} = \frac{W_c L}{6} = \frac{1200 \times 11.5}{4 \times 6} = 575 \text{ yard tons,}$$

making $h = 9.30 - 0.60$ yards $= 8.70$ yards.

and $b = 0.70$ yards, the steel area A_s is found to be 9 square inches. 10 bars $1\frac{1}{8}$ inches diameter represent an area of 9.94 square inches.

$$\text{Shear force } Q = \frac{1}{2}\frac{W_c}{4} = \frac{1200 \text{ tons}}{8} = 150 \text{ tons.}$$

$$\text{Shear stress} = \frac{150}{0.7 \times 8.7} = 25 \text{ tons per sq. yard.}$$

$= 45$ lbs per square inch.

LOAD CONDITION No. 2.

The kerb is lowered to R.L. +246.00

The deck slab is now suspended on the transversal ribs and is calculated as a continuous slab.

Span $= 3.6$ yards.

The load is composed of the weight of the deck and light concrete. $W = 8.06$ tons per square yard.

$$\text{Bending Moment in span} = M_1 = \frac{WL^2}{18} = 5.82 \text{ yard tons/yard.}$$

$$\text{Bending Moment over support} = M_0 = \frac{WL^2}{12} = 8.7 \text{ yard tons/yard.}$$

$h = 0.70 - 0.05$ yards
$b = 1$ yard.

With the help of the formula $A_s = \dfrac{M}{f_s\,(h - a - \frac{n}{3})}$ the reinforcement is found to be 1.4 sq. inches/yard in span.

Area of 4 bars $\frac{3}{4}''$ diameter $= 1.768$ square inches.

Reinforcement in the support is found to be 2 square inches.

Area of 5 bars $\frac{3}{4}''$ diameter $= 2.21$ square inches.

The load in section A—B

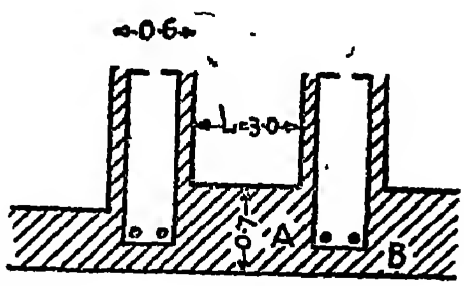


FIG. 35

$W_s = We = 8.06 \times 3 = 24.2$ tons/yard.

$$\text{Steel required} \frac{53208 \text{ lbs.}}{17500 \text{ lbs.}} = 3.2 \text{ square inches.}$$

Area of 4 bars $1''$ diameter $= 3.14$ square inches.

LOAD CONDITION No. 3 (See fig. 1/3 plate 3)

Kerb lowered down to the R.L. + 246.00

R.L. flood level = R.L. + 283.00

Pier built up to R.L. + 312

These conditions are necessary to compute the stressess in transversal walls. The filling above the deck makes a homogeneous body with the transversal ribs taking off the active compressive forces.

When considering the weight of a span of 3.60 yards and ½ of a pier and the buoyancy, we find that the weight of the caisson + light concrete + pier comes to :

$$W_1 = 246 \text{ tons}$$

Weight of earth resting on walls to $W_2 = 128$ tons

$$W = W_1 + W_2 = 374 \text{ tons}$$

With the help of Moller's table we are able to find the various combined earth and water pressures for different heights and these are :

$$p_1 = ghn = 1 \times 12.20 \times 0.326 = 3.98 \text{ tons/square yard.}$$

$$n = 0.326 \text{ (Moller's table).}$$

$$p_2 = ghn = 1 \times 14.50 \times 0.326 = 4.73 \text{ tons/square yard.}$$

$$E_1 = 3.98 \times \frac{12.2}{2} \times 3.60 = 24.3 \text{ tons/yard} \times 3.60 = 87.5 \text{ tons.}$$

$$E_2 = \frac{3.98 + 4.73}{2} \times 2.3 \times 3.6 = 10 \text{ tons/yard} \times 3.60 = 36 \text{ tons.}$$

Total E = 123.5 tons.

Wall's friction $R = {}_{\eta}E = 0.5 \times 123.5 = 62$ tons.

Reaction $A = W - R = 374 - 62 = 312$ tons.

Thrust $H = 0.23\,A = 0.23 \times 312 = 72$ tons.

$$Me = (A + R) \times 5.65 - W_1 \times 1.88 - W_2 \times 4.40 + H \times 2.30 + E_1 \times 4.10 - E_2 \times 120 = 1570 \text{ yards/ton.}$$

$$N = H - E = 72 - 123.5 = -51.5 \text{ tons.}$$

Assuming effective depth $h = 7.00 - 0.10 = 6.90$ yards

and $b = 3.6$ yards.

g = weight of water equal to 1 ton.

$$\frac{Me}{bh^2} = \frac{1570}{3.6 \times 6.9^2} = 9.1 \text{ tons/yards}^2 = \frac{20384 \text{ lbs.}}{1296 \text{ inches}}$$

$$= 15.9 \text{ lbs./square inch.}$$

$$\frac{N}{bh} = \frac{51.5}{3.6 \times 6.9} = 2.1 \text{ tons/yards}^2 = \frac{4700}{1296} = 4 \text{ lbs/square inch.}$$

These Moments result in a compressive stress $f_c = 220$ lbs./square inch when area of steel 23 square inches is used, which means 25 bars of 1⅛" diameter. 16 bars have been used in the ribs and 9 placed in the deck slab.

THE KNIFE EDGE REINFORCEMENTS

$2W = 2 \times 374 = 748$ tons.

$\frac{748}{36 \times 11.5} = 18.06$ ton/yards^2

The area of the pier on the bottom :

$A_p = 161.3$ yards^2

Total weight of pier = 2900 tons.

Total length of the knife :

$11.5 + 2\ (11.35 + 6.00) + 3$
$= 49.2$ yards.

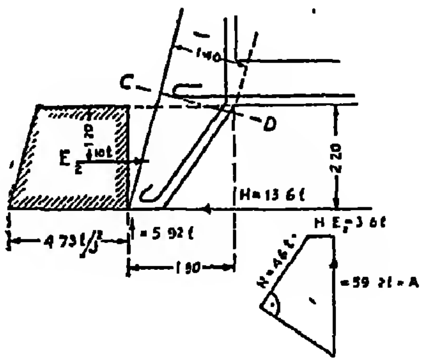


FIG. 36

Reaction $A = \frac{2900}{49.2} = 59$ tons/yards and $H = 0.23$.

$A = 13.6$ tons/yards.

From the section C—D it is easy to follow the calculations for Bending Moments.

$M_e = A \times 1.90 + H \times 2.20 - E_2 \times 120 = 131$ yards/ton.
and as per diagram of forces, (funicular diagram),
$N = 46$ tons.

SHEAR FORCES.

Assuming $h = 1.40 - 0.05 = 1.35$ yards and $b = 1$ yard.

$\frac{M_e}{bh^2} = \frac{131}{1 \times 1.35^2} = 100$ lbs/square inch.

$\frac{N}{bh} = \frac{46}{1.135} = 45$ lbs/square inch.

This Bending Moment will cause a compressive stress, $f_c = 600$ lbs. per square inch with an area of steel of 22 square inches per running yard *i.e.*, when 6 bars $1\frac{5}{8}$ inches diameter are used.

Mr. Nilsson would win my boundless admiration if he could guess all these dimensions correctly without wasting any time on calculations.

ANNEX A.

List of Authors Referred to by Dr. Korni.

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7. W. S. Housel. 1929.
A practical method for the selection of foundations
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PAPER No. L—39.

Mr. G. P. Bhandarkar (Chairman):—I request Mr. Nicolaides to introduce his paper.

The following paper was then taken as read :—

PAPER No. L—39.

IMPACT ON REINFORCED CONCRETE ROAD BRIDGES AS COMPARED TO STEEL BRIDGES.

By

E. P. NICOLAIDES, B. Sc., DIPL. C. E., E. C. P., M. Soc., C. E. (FRANCE)

PART I.

1. The Indian Roads Congress Impact Formula.

The Codes of Practice for Road Bridges in India, issued by the Indian Roads Congress at its Lucknow Session in 1937, specifies an impact percentage factor :

$$(1)\ I=\frac{1}{2}\times\frac{65}{45+L\frac{n+1}{2}}$$

subject to a maximum value of 50 per cent. In this formula L=the length in feet of the member considered and n the number of traffic lanes of the bridge. The attached graph No. 1 shows the variation of this impact factor in relation to the only variable L and for the two cases of n=1 and n=2. The curves on the right are the same with a three times larger scale for L in the range of spans from 0 to 100 feet.

The curves are branches of an equilateral hyperbola asymptotic to the axis of L. The impact factor decreases very rapidly from 50 per cent to 10 per cent in the range of spans from 0 to 300 feet and becomes nearly a constant for greater spans. The decrease in the impact factor is in inverse relation to the square of the span as it can be seen easily by deriving the formula (1) in respect of L :

$$\frac{DI}{DL}=-\frac{n+1}{4}\times\frac{65}{\left(45+L\frac{n+1}{2}\right)^2}$$

The impact factor is also reduced when the number of traffic lanes of the bridge is increased. As specified in the above mentioned Indian Roads Congress Codes, this impact formula is to be applied to both steel and reinforced concrete bridges of any type and must be used for any part of the bridge structure *i. e.*, deck slab, cross beams, longitudinal beams, main girders, etc.

2. The Merits of the Formula.

With the exception of the slight modification taking into consideration the relief of impact on bridges having more than one traffic lane, the Indian Roads Congress impact formula is the same as the one specified for Road Bridges by the Bridge Rules of the Indian Railway Board namely :

$$(2)\ I=\frac{1}{2}\times\frac{65}{45+L}$$

Both the above formulæ have no direct experimental or theoretical justification; they are simply more or less arbitrary deductions from the basic impact formula:

$$(3) \quad I = \frac{65}{45+L}$$

adopted by the Indian Railway Regulations for 1933 for Broad and Meter Gauge Steel Railway Bridges, as a result of the impact experiments on Indian Steel Railway Bridges carried out by the Indian Railway Bridge Standards Committee.

The Indian Roads Congress Committee, faced with the task of regulating the impact coefficients in the Indian Roads Congress Code, thought it best to accept in this instance almost unrestrictedly the recommendations of the Railway Board, and the reasons given for such a choice are:

(*a*) The importance of the Research carried out by the Indian Railway Bridge Standards Committee on the impact effects on bridges.

(*b*) The absence of any investigation in India on the impact effects on Road Bridges.

(*c*) The necessity to keep the same impact standards for Road Bridges irrespective of whether they are controlled by the Railways or other authorities.

(*d*) The reduction of impact with increasing spans afforded by the formulæ (1) and (2) which while prescribing heavy impact coefficients for spans less than 20 feet (floor systems) provide for quite moderate values when the span is increased beyond 80 feet.

As to the question whether the same formula could be reasonably applied to both Steel and Reinforced Concrete Road Bridges the arguments in favour of a common formula are given as follows by the Indian Roads Congress Committee:

(*a*) The members in which the above formula gives high impact values are the floor systems of the bridges and for these some sort of concrete slab or the like is always used irrespective of whether the bridge is in Steel or in Reinforced Concrete.

(*b*) When Reinforced Concrete is the structural material throughout, in bridges of more than 100 feet spans or in arches of fair size, the dead load effects are always so high in comparison to the live load effects that a reduction in the impact coefficients for the case of reinforced concrete bridges would only give negligible savings not justifying a differentiation between concrete and steel.

On the other hand the main criticisms against these formulæ may be summarized as follows:

(*a*) For a given span they do not differentiate between the members of the bridge directly bearing the effects of the

live load and those members, such as the main girders in certain types of bridges, which are only indirectly loaded through the reactions of the decking. In the same way the cushioning effect of thick deck slabs or other filling or surfacing is totally ignored.

(*b*) For the small spans upto about 100 feet the impact specified for the main girders appears generally high.

(*c*) No relief of impact is accorded to structures with great stiffness, low ratio of live to dead load and important internal frictional resistance where the vibration frequencies and amplitudes are small and the damping effect considerable.

All the arguments given above in favour of the impact formulæ (1) and (2) appear rather incomplete and cannot be accepted without further discussion.

A close study of the Reports published between 1917 and 1933 by the Indian Railway Bridge Standards Committee shows that the impact tests and other similar experiments carried out by this Body, are limited to Steel Railway Bridges only, and further that the results are only conclusive for spans greater than 80 feet. In this connection it may be of interest to reproduce here the following extract from the seventh Report of the Committee giving the reasons for their conclusion to adopt the formula (3) given above.

"The formula $\frac{65}{45+L}$", the Report states, "was admittedly constructed to cover impact on spans where resonance occurs and on such spans it has a definite interpretive meaning. On short spans, however, it has no such interpretive meaning. The Committee found it convenient to extend the curve backwards to cover the case of short spans and their justification was that by so doing they covered the requirements as shown by available experimental evidence on short spans".

This remark in itself shows how limited is the field covered by the impact tests of the Indian Railway Bridge Standards Committee and it is misleading to assign to these tests a greater importance than is claimed by the experimenters themselves.

It should be noted further that the results of these tests give only aggregate values of the observed impacts and no attempt has been made to analyse the relative importance of the various dynamic factors. Such an analysis however is of primary importance if it is intended to deduct, from the actual test results, information concerning types of Bridges and loads different from those actually tested.

Admittedly the absence of impact tests on Road Bridges is a serious handicap for the establishment of a rational impact formula for such bridges, and sooner or later the Bridge Engineers of this country will have to devote the necessary time and funds required for a methodical investigation of the dynamical behavior of Road Bridges. The lack of direct experimental evidence is not, however, a reason for accepting roughly approximate and almost arbitrary solutions of the problem,

The theory of Bridge Dynamics has been sufficiently developed during recent years to enable a general, for practical purposes, almost complete and accurate solution of the problem. By splitting the dynamical action of the loads into its simple components and studying each one of these separately, this theory provides a perception and interpretation of the facts much clearer than could be revealed through a gross registration, by measuring instruments of the complicated and highly interconnected dynamic stresses and strains.

Further, the theoretical results applied to the case of Railway Steel Bridges are satisfactorily confirmed by the available experiments in this field, justifying thereby the applicability of the general assumptions and the procedure of the calculations to other types of bridges and loads.

Regarding the necessity to keep the same standards of design for all Road Bridges it should be borne in mind that Road Bridges under the control of the Railways are only a particular case and it is against all logical principles to apply the conclusions drawn from this particular case to the general case of all Road Bridges. I do not think that the Railway Authorities pretended to any degree of accuracy in deriving an impact formula for all their Road Bridges by simply halving the results of the Railway formula No. 3. Such a procedure has only the doubtful merit of expediency and can only be acceptable to the Railways for the simple reason that, their own Road Bridges being always far less important than the Railway Bridges, excessive safety in the design of this class of Road Bridge would have only a negligible effect on the Railway Budget.

For Steel Road Bridges the relation between the impact coefficient and the span as specified by the Indian Roads Congress formula can be considered as satisfactory, although for spans smaller than 80 feet lower impact coefficients would appear acceptable. For the floor systems also when they are protected only by a hard and thin wearing coat an impact coefficient of 50 per cent as specified by the Indian Roads Congress Code is more or less in order although a number of Continental Regulations limit this impact to 40 per cent only. For these members of the bridge structure, the ratio of dead to live load and their stiffness being generally small, the dynamic effects are naturally more pronounced.

It is, however, a fallacy to state that the members of a bridge structure for which the Indian Roads Congress formula gives high impact values are the floor systems only. For instance, in the case of a small bridge of one traffic lane of 10 feet and 20 feet span of main girders, the Indian Roads Congress Code specifies the same impact value of 50 per cent for the 6 inches thick deck slab having a dead load of 110 pounds per square foot as for one main beam carrying a dead load of 850 pounds per running foot and having a stiffness 50 times greater. To show the fallacy of such a conclusion and to elucidate the dominating influence of the dead load and stiffness of a structure on its dynamical behaviour, are the main objects of this paper.

In the arguments for a common impact formula for steel and reinforced concrete bridges the case of the short span main girders has been altogether overlooked ; yet nobody will deny that in a country like India, where usually the foundation of bridges can be carried out almost in the dry at very little cost, Reinforced Cement Concrete short span Road Bridges

are the most economical and being as such very common, they form a large item of the total bridge budget. Upto date, it is chiefly in the range of these short spans that reinforced concrete finds a competitive field against steel road bridges, and in this field again owing to the smaller dead to live load ratios the importance of the live loads bears considerably on the economy of the design of Reinforced Cement Concrete Bridges.

With the widely differing main dynamical characteristics of steel and reinforced concrete bridges a revised impact formula for Reinforced Cement Concrete Bridges appears a necessary complement of the Indian Roads Congress Code portion dealing with reinforced concrete.

The main scope of regulations for the design of Road Bridges is to provide for the public safety consistent with a thrifty investment of the taxpayers money on remunerative bridge schemes; at the same time such regulations must offer to the builder a basis on which he can formulate his proposals without fearing to find himself outdone by bolder competitors.

To achieve this scope the regulations must offer to the Designer every opportunity and latitude to take advantage of the well established properties and qualities special to each structural material.

PART II

The dynamic action and its elementary causes.

In order to understand clearly the process of the dynamic action of bridges it will be necessary to give here a concise explanation of the dynamical phenomenon and to enumerate its various known causes.

Take the simplest case of a freely supported beam of negligible self weight, at a certain point of which a constant load P is applied suddenly. In its tendency to equilibrate the load P the beam deflects and is put under stress. The internal stresses of the beam increase gradually from zero whereas the load maintains its full value from the moment it is applied on the beam; as a result the potential energy accumulated in the beam through the deformation work remains, in the initial stages, less than the work produced by the load P sinking with the deflection of the beam; the excess external work passes on to the mass of the beam in the form of motion energy reaching its maximum value when the shape of the beam corresponds to the requirements of static equilibrium.

Owing to the unbalanced accumulated energy the beam however is driven downwards away from this position and consequently the load P sinks further producing additional work. But this time the deformation work of the internal stresses, increasing with the square of the deflection, becomes greater than the external work of the load. The downward movement of the beam is rapidly damped and the beam comes to an instantaneous rest when its deflection attains the double of the static value From this moment the oscillation starts again on an upward trend

This mechanical explanation of the vibrations of the beam, raising from the sudden application of a load, has very often led to the conclusion that a moving load is bound to stress the beam twice as much as under static conditions. Such a conclusion however is not confirmed either theoretically or experimentally, the dynamic deflection being found either way only slightly higher than the static deflection. A load moving on the beam is not a suddenly applied load in the sense of the above explanations Assume for instance that the beam is given a camber such as to provide at the centre of its span a rise f equal to the static deflection produced by the load P at centre When the load, entering the beam from one end, reaches the centre, the internal deformation work corresponds to the static deflection f but the level of the load P has not changed with respect to this position of the centre, preventing thus an excess work of the external load over the internal forces. This remark shows incidentally the beneficial effect of the longitudinal camber on bridges supporting heavy and fast moving loads.

The vibration of a bridge, and more generally of any elastic body, can be of two different types:

(*a*) The free vibrations caused by a single sudden disturbance of the static equilibrium, the ensuing movement of the bridge remaining unhindered by any other external forces.

(b) The forced vibrations resulting through the action of an impressed periodic force.

The period of vibration is the time required by a particle of the vibrating body to move once away from and return again to the same one extreme position of its movement; instead of the period it is often more convenient to use the frequency of vibration n which is the number of periods per second.

There are two important distinctions between free and forced vibrations; the frequency of a free vibration depends on the constitution of the vibrating body whereas the frequency of a forced vibration is determined by the periodic force; a free vibration dies out sooner or later on account of friction but a forced vibration continues as long as the periodic force acts. It can be easily seen that a forced vibration can never exist alone. At the first application of the generating periodic force the body acted upon will undergo free vibrations and only gradually the forced vibration may become predominant. After the impressed periodic force has ceased to act the motion of the vibrating body reverts again into a free vibration. As is well known from the problems of Acoustics, the vibration of an elastic body is a combination of an infinite number of simple harmonic motions of the sine form. The component with the largest period is called the fundamental mode of vibration, the others with lesser period being the harmonics.

The frequency of the free vibration of a bridge is one of its most important dynamic characteristics. A coincidence in the frequencies of the free and forced vibrations leads to an abnormal increase of amplitude; this is the phenomenon called resonance or synchronism.

For the case of a freely supported beam of span L constant moment of inertia I and uniform dead load w per unit length, the frequencies of free vibration derived from the partial differential equation of transverse vibrations of a prismatic body are:

$$n = \frac{\pi k^2}{2L^2} \sqrt{\frac{gEI}{w}}$$

where $k = 1, 2, 3$ etc.
E = elastic modulus
g = acceleration of gravity.

with $k = 1$ the frequency of the fundamental mode is obtained,

$$n_1 = \frac{\pi}{2L^2} \sqrt{\frac{gEI}{w}}$$

the other successive values of $k = 2, 3$, etc., giving the frequencies of the accompanying harmonic modes.

As the static deflection of the beam in the centre is

$$\delta_w = \frac{5}{384} \times \frac{wL^4}{EI}$$

the fundamental period can be expressed

$$\frac{1}{n_1} = 5.6 \sqrt{\frac{\delta_w}{g}}$$

and with g = 32.2 feet per second and δ_w also in feet

$$\frac{1}{n_1} = \sqrt{\delta_w}$$

Except for very big spans δ_w is always much smaller than an inch and consequently the period of vibration is only a fraction of a second. The smaller the period of free vibration the more difficult it becomes for the external forces to attain this period and the lesser the chances for resonance. This is the reason why in short spans resonance is almost impossible and why for the longer spans a stiffer bridge with greater depth to span ratio is more advantageous.

For reinforced concrete bridges the economical depth to span ratio is always around 1 10th but for steel bridges smaller values are more common: these, however, do not appear satisfactory from the dynamical point of view.

The tables 1 and 2 attached give an idea of the values of n_1 for the case of a Steel Railway Bridge and a Reinforced Concrete Road Bridge, for various spans.

The Railway Bridge carries a single broad gauge track on two main beam girders; the live load is the His Majesty's standard of 1926 given in the Bridge Rules (year 1933) of the Indian Railway Board, the equivalent uniformly distributed load being taken from pages 36 to 39 of the above rules. The dead load in tons per Rft. is taken from the formulæ:

$w = 0.25 + 0.005L$ for spans from 10 to 100 feet and
$w = 0.50 + 0.0025L$ for spans from 100 to 400 feet.

where L is the span in feet. The values obtained from these formulæ are in satisfactory agreement with the dead loads of the railway bridges tested by the Indian Bridge Standards Committee.

The Reinforced Concrete Road Bridge has a clear roadway of 12 feet bordered by 6 inches thick copings on either side. The deck slab is 6½ inches thick and the road surfacing consists of 3 inches thick reinforced concrete. The two main beams carrying the slab are spaced 7 feet apart. The dead load in tons per running foot can be taken from the lane of the formula:

$$w = 0.70 + 0.0004L$$

The live load is the Indian Roads Congress Standard Loading for one traffic lane of 10 feet.*

From the comparison of the frequencies it appears that there is an appreciable difference in this respect between Steel and Concrete Bridges notwithstanding the fact that in the latter the increased stiffness is balanced by the increased dead load. It will be seen later that the greater dead to live load ratios of Reinforced Cement Concrete Bridges bring a considerable reduction of the dynamical action.

* The knife edge load has also been replaced by its equivalent uniformly distributed load.

The main causes of the vertical dynamical action on a bridge are:

(1) the speed, v with which the live load P changes position on the bridge.

(2) the centrifugal forces due to the curved trajectory of the moving load, resulting from the deflection of the bridge.

(3) the unbalanced weights of the locomotive wheels and the alternating action of the driving pistons.

(4) the railjoints and the flattening of the wheels in the case of railway bridges or the unevenness of the wearing surface in the case of road bridges.

3. The effect of the speed of the moving loads.

For a single point load P moving with the constant speed v on a freely supported beam of span L and constant moment of inertia I, the dynamic deflection is the sum of a series of sine vibrations expressed by

$$(4)\quad \delta = \frac{2PL^3}{EI\pi^4}\left[\sum \frac{\sin\frac{k\pi x}{L}\,\sin\frac{k\pi vt}{L}}{k^4\left(1-\frac{c^2}{k^2}\right)} - c\sum \frac{\sin\frac{k\pi x}{L}\,\sin\frac{k}{c}\times\frac{k\pi vt}{L}}{k^5\left(1-\frac{c^2}{k^2}\right)}\right]$$

where x is the distance of the section from the left support, t the time, E the modulus of elasticity and c a coefficient characteristic of the dynamical behaviour of the beam; c is related to the speed of the load and the frequency n_1 of the free vibrations of the beam by the formula:

$$c = \frac{v}{2Ln_1}$$

For a speed v of 100 feet per second (68 miles per hour) in the case of the Railway Bridge and 75 feet per second in the case of the Reinforced Cement Concrete Road Bridge the values of c are:—

Railway bridge; speed 100 feet per second.

L:	10	20	30	50	70	100	150	250	400
n_1:	41	26	19.5	12.6	9.5	6.9	5.2	3.5	2.5
c:	0.122	0.096	0.086	0.080	0.075	0.072	0.064	0.057	0.05

Reinforced Cement Concrete Road Bridge; speed 75 feet per second.

L:	10	20	30	50	70	100
n_1:	19.0	14.6	12.0	8.5	6.3	4.5
c:	0.198	0.129	0.105	0.089	0.085	0.083

Returning now to the formula expressing the deflection δ it will be seen from the two component sums of sine terms that the final movement is the result of the superimposition of two totally different types of vibrations.

The one vibration expressed by the terms of the first sum has a period of $\frac{2L}{v}$ depending from the speed of the moving load; a complete oscillation requires twice the time taken by the load to run over the beam; the movement is very slow and the deflection of the beam takes the form shown in full on figure 1.

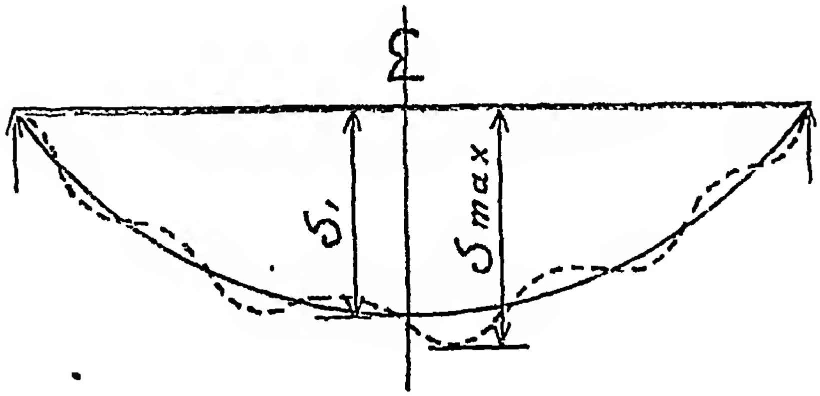
The second vibration expressed by the terms of the second sum of formula (4) has a period T given by:

$$\frac{k}{c} \times \frac{k\pi\, vT}{L} = 2k$$

or: $$T = \frac{2cL}{kv} = \frac{1}{kn_1}$$

which is the same as the period of the free vibrations of the beam. The amplitudes however, are considerably reduced on account of the coefficient c and the resulting deflection takes the form shown in dotted line? on figure 1.

FIG. 1.



If in (4) v = o, the coefficient c is nil and the second sum disappears. In the first sum vt = u gives the position of the load and the resulting expression of δ is the static deflection of the beam at a section x under the point load P at a distance u from the support.

$$(5) \quad \delta_P = \frac{2PL^3}{EI\pi^4} \sum \frac{1}{k^4} \sin \frac{k\pi x}{L} \sin \frac{k\pi u}{L}$$

for $u = x = \frac{L}{2}$ the static deflection in the centre of the beam is

$$\delta_P = \frac{2PL^3}{EI\pi^4}\left(1 + \frac{1}{3^4} + \frac{1}{5^4} + \ldots\right)$$

But the sum

$$1 + \frac{1}{3^4} + \frac{1}{5^4} + \ldots + \frac{1}{(2k+1)^4} = \frac{\pi^4}{96}$$

and $\delta_P = \frac{PL^3}{48\,EI}$ the same as obtained in ordinary Statics.

A comparison of the static deflections given by (5), with the dynamic deflections given by the first sum of formula (4) shows that the latter are $\frac{1}{1-c^2/k^2}$ times greater than the former. For $k = 1$, and the maximum value of $c = 0.198$ given above, the dynamic deflection is at the most:

$$\left(\frac{1}{1-0.198^2} - 1\right) 100 = 4 \text{ per cent greater than the static deflection.}$$

When $\frac{c^2}{k^2} = 1$ or $v = 2kLn_1$, the expression (4) takes the indeterminate form : $\infty - \infty$

If the indetermination is set aside the expression obtained is :

$$(6) \quad \delta = \frac{PL^3}{k^4 \pi^4 EI}\left[\sum \sin \frac{k\pi x}{L} \sin \frac{k\pi vt}{L} - \frac{k\pi vt}{L} \sum \sin \frac{k\pi x}{L} \cos \frac{k\pi vt}{L}\right]$$

and the amplitudes in the second sum increase with the time t which is the resonance condition. For the fundamental mode of vibration ($k=1$) the critical speed for resonance is $v = 2Ln_1$ and from the values of n_1 given in tables 1 and 2, the critical speed remains above 560 miles per hour for the Railway Bridge and 260 miles per hour for the Reinforced Cement Concrete Road Bridge, this shows that in either case resonance is practically impossible.

In the expression (4), it will be noted that the amplitudes of the harmonics are divided by the 4th and 5th power of the order k of the harmonic in each of the component vibrations. These amplitudes are therefore negligible and it will be sufficient to deal with the fundamental mode only, reducing the sums to their first member.

From equation (5), the statical deflection at a section x with the load P at a distance $u=vt$ from the left support is :

$$\delta_s = \frac{2\,PL^3}{EI\pi^4} \sin \frac{\pi x}{L} \sin \frac{\pi vt}{L}$$

and for the load at the centre of the span :

$$\delta_{sm} = \frac{2\,PL^3}{EI\,\pi^4} \sin \frac{\pi x}{L}$$

Comparing now with the expression (4)—the first member with $k = 1$ is only considered in each sum, the following relation is obtained between the dynamical and statical deflections :

$$(6a) \quad \delta = \frac{\delta_s}{1-c^2} - \frac{c}{1-c^2}\delta_{sm} \sin \frac{1}{c}\frac{\pi vt}{L}.$$

In the time $\frac{L}{v}$ taken by the load to run over the beam, the member $\sin \frac{\pi vt}{cL}$ changes sign many times but its worst possible value is -1 for which :

$$\delta = \frac{1}{1-c^2}\left(\delta_s + c\,\delta_{sm}\right)$$

Finally with the load at the centre of the span

$$\delta_{max} = \frac{1}{1-c^2}\left(\delta_{sm} + c\,\delta_{sm}\right) = \frac{\delta_{sm}}{1-c}$$

The dynamic increase of the deflection is :

$$\delta_{max} - \delta_{sm} = \delta_{sm}\frac{c}{1-c} \quad \text{and therefore}$$

$$(7) \qquad \boxed{I_1 = \frac{100\,c}{1-c}}$$

is a maximum limit of the percentage of increase in the deflection, due to the dynamical action arising from the speed of a single moving load.

The above conclusion derived for the case of a single point load can be extended also to a train of loads. Tables (3) and (4) give the values of the percentage I_1 for the Railway Steel Bridge and the Reinforced Cement Concrete Road Bridge considered above. It will be seen that the impact on the Reinforced Cement Concrete Road Bridge, as far as the velocity of moving loads is concerned, is greater than on the Steel Railway Bridge.

The live load has been assumed upto now as directly bearing on to the bridge; in practice, however, all heavier vehicles using the bridges are provided with suspension springs, the action of which reduces considerably the dynamical effects.

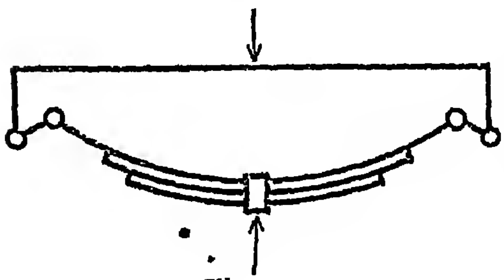


Fig. 2

When a load is acting on the bridge through a suspension spring the bottom of the spring follows the vibration of the bridge but the load above, which is suspended at the ends of the spring, undergoes a different forced vibration. The ratio of amplitude of this forced vibration to the amplitude of the vibration of the bridge is :

$$(8) \quad f = \frac{\left(\frac{n'}{n}\right)^2}{1 - \left(\frac{n'}{n}\right)^2}$$

where n' is the proper frequency of the spring and n the frequency of the vibrations of the bridge; the same ratio applies also to the accelerations of the two vibrations. n' is a characteristic of the spring construction and may take a value between 1 and 4. For the vehicles considered in this paper, an average value of $n' = 2.5$ will be adequate. For the case of the free vibrations of the bridge, n varies considerably with the span and type of bridge as shown in tables (1) and (2). f will remain smaller than one for all values of :

$$n > n'\sqrt{2} \quad \textit{i.e.}, \; n > 3.5$$

For the smaller spans where n is great, f is very small evidencing the importance of the suspension of loads in bridges of small spans.

4. The effect of the centrifugal action.

In the foregoing calculation of the vibrations arising from the velocity of the moving loads, the only inertia forces considered in the dynamic equilibrium were those due to the inertia of the beam itself namely $\frac{w}{g} \times \frac{d^2\delta}{dt^2}$ the general equation of the vibrations being:

$$(9) \quad \frac{w}{g}\frac{d^2\delta}{dt^2} = - EI \frac{d^4\delta}{dx^4} + w + P\ (xt).$$

If, however, the moving load P (xt) is bearing directly on the beam as in the case of vehicles without any springs, the load itself follows the motion of the beam and its inertia forces must be taken into account; the above equation (9) becomes:

$$(10) \quad \frac{w+P(xt)}{g} \times \frac{d^2\delta}{dt^2} = - EI \frac{d^4\delta}{dx^4} + w + P\ (xt).$$

When the load P (xt) is resting on springs, the amplitude of its movement is f times smaller than the amplitude of the beam and the equation (10) becomes:

$$(11) \quad \frac{w+f\,P\ (xt)}{g} \times \frac{d^2\delta}{dt^2} = - EI \frac{d^4\delta}{dx^4} + w + P\ (xt).$$

An accurate solution of such an equation is not possible but for practical purposes the following method gives sufficient approximation.

Equation (11) may be written in the form:

$$\frac{w}{g} \times \frac{d^2\delta}{dx^2} = - EI \frac{d^4\delta}{dx^4} + w + P\ (xt) \left[1 - \frac{f}{g}\ \frac{d^2\delta}{dt^2} \right]$$

but: $\frac{d^2\delta}{dt^2} = \left(\frac{dx}{dt}\right)^2 \frac{d^2\delta}{dx^2} = - \frac{v^2}{R}$

where R is the radius of curvature of the beam.

Hence:

$$(12) \quad \frac{w}{g} \times \frac{d^2\delta}{dt^2} = - EI \times \frac{d^4\delta}{dx^4} + w + P\ (xt) \left[1 + \frac{f}{g} \cdot \frac{v^2}{R} \right]$$

In this form, the factor $\frac{fv^2}{gR}$ shows the additional pressure on the beam due to the centrifugal force resulting from the movement of the load P (xt) on the curved trajectory of the beam. The approximation now consists in assuming that the deflection of the beam increases or decreases in the same proportion as the load P (xt) is increased or decreased by the factor $\frac{f}{g}\frac{v^2}{R} = - \frac{f}{g} \times \frac{d^2\delta}{dt^2}$ due to the centrifugal force.

Reverting to the expression of δ found in para (3) above:

$$\delta = \frac{2PL^3}{EI\pi^4} \left(\sin \frac{\pi vt}{L} - c \sin \frac{1}{c} \frac{\pi vt}{L} \right) \sin \frac{\pi x}{L}$$

we get:

$$\frac{d^2\delta}{dt^2} = \frac{2PLv^2}{EI\pi^2} \left[- \sin \frac{\pi vt}{L} + \frac{1}{c} \sin \frac{1}{c} \times \frac{\pi vt}{L} \right] \sin \frac{\pi x}{L}$$

or with $c^2 = \frac{v^2}{4L^2 n_1^2} = \frac{vL^2 w}{\pi^2 EIg}$

$$(13) \quad \frac{d^2\delta}{dt^2} = \frac{2Pg}{wL}\left[- c^2 \sin\frac{\pi vt}{L} + c \sin\frac{1}{c} \times \frac{\pi vt}{L}\right] \sin\frac{\pi x}{L}$$

from where it will be seen that the acceleration is composed of two parts, the first one being related to the forced vibrations with the period $\frac{2L}{v}$ considered above and the second one being related to the accompanying free vibrations.

A reference to figure 1 shows that the curvature of the beam due to the forced vibrations does not change sign throughout the span of the beam. On such a trajectory, except for very small spans, the springs remain more or less locked and therefore f must be taken as equal to 1.

On the contrary, for the free vibrations the deflection is an undulating curve and consequently spring action is bound to occur for these vibrations. It should be noted that the effect of the centrifugal force does not actually depend directly from the curvature of the beam, but from the curvature of the trajectory followed by the centre of gravity of the loads. With the undulated trajectory of the beam and the superimposed action of the springs, the centre of gravity of the live load portion borne on springs moves practically on a straight line and the effect of the centrifugal force is almost negligible for this part of the load.

In estimating the dynamic effect of the centrifugal force, it is therefore necessary to examine separately the effect of the two types of vibration

For the forced vibrations having the period $\frac{2L}{v}$ the acceleration is :—

$$\frac{1}{g} \times \frac{d^2\delta}{dt^2} = - \frac{2P}{wL} c^2 \sin\frac{\pi vt}{L} \sin\frac{\pi x}{L}$$

and for the load at the centre of the span the acceleration in the same centre section is

$$\frac{1}{g} \times \frac{d^2\delta}{dt^2} = - \frac{2P}{wL} c^2$$

depending mainly on the ratio of live to dead load.

To extend the result to the case of a train of loads, let M be the maximum bending moment at centre of the span due to this train of loads. An equivalent point load at centre giving the same bending moment would be $P' = \frac{4M}{L}$ and for our purpose this single point load P′ can replace the train of loads. The centrifugal force becomes

$$\frac{v^2}{gR} = - \frac{1}{g} \times \frac{d^2\delta}{dt^2} = \frac{8\ M}{wL^2} c^2$$

With an equivalent uniformly distributed live load on the whole span

$$M = \frac{pL^2}{8}$$

and, therefore, $\frac{v^2}{gR} = \frac{p}{w} c^2$

$100 \frac{p}{w} c^2$ gives the percentage of the additional load due to the centrifugal force related to the forced vibrations. Including the effect of

speed as per para 3 above, the percentage of increase will be :*

(14) $$\boxed{I_2' = \frac{100}{1-c} \times \frac{P}{W} \times c^2}$$

In the attached tables (7) and (8) the values of I_2' have been calculated for the various spans of the Steel Railway Bridge and the Reinforced Cement Concrete Road Bridge. For the span of 10 feet the impact on the Reinforced Cement Concrete Bridge is more than three times smaller and for the greater spans it remains about ten times smaller than the impact on the Steel Railway Bridge.

For the free vibrations having the period $\frac{1}{n_1}$ the acceleration is :

(15) $$\frac{f}{g} \times \frac{d^2\delta}{dt^2} = \frac{2\,Pf}{w\,L}\, c \sin \frac{1}{c} \times \frac{\pi\, vt}{L} \sin \frac{\pi\, x}{L}$$

f being the reducing factor due to spring action. In the centre section $x = \frac{L}{2}$ the maximum occurs when $\sin \frac{\pi\, vt}{cL} = 1$, that is, when the load P is at a distance $vt = u = \frac{kcL}{2}$ from the left support, k being equal to 1, 2, 3, etc. ; $\frac{f}{g}\,\frac{d^2\delta}{dt^2} = \frac{2fP}{wL}\,c.$

Here it will be seen that in the case of a train of loads P_1, P_2, P_3, etc. at distances u_1, u_2, u_3, from the left support, the dynamic increase in the centre takes the form of a sum :

$$\frac{2\,fc}{wL}\left[P_1 \sin \frac{\pi u_1}{cL} + P_2 \sin \frac{\pi u_2}{cL} + P_3 \sin \frac{\pi u_3}{cL} \text{ etc.} \right]$$

Ordinarily, however, the sine terms have different signs and the centrifugal forces of the various loads counteract each other. Only when the spacing u from one load to the next is the same everywhere and such as to have $\frac{u}{v} = \frac{2cL}{v} = \frac{1}{n_1}$ = to the period of the free vibrations of the bridge, then only is it possible to have an accumulation of the dynamic effect. Such a coincidence is, however, extremely rare and it is generally sufficient to calculate the percentage of additional load $100\,\frac{2\,f\,Pc}{wL}$ taking P as the maximum possible axle load.

For the Steel Railway Bridge examined previously P will be the heaviest axle of the H. M. Standard Loading, *i.e.* 28 tons. The portion of this load resting on springs can be taken as 80 per cent *i.e.*, 22 tons, the remaining 6 tons being the load of the wheels themselves, their axle and other connected parts which rest directly on the rails.

In the case of the Reinforced Cement Concrete Road Bridge, take a maximum axle load of 12 tons out of which 9 tons will be taken as resting on springs.

With $P = P_1 + P_2$, P_1 being the spring borne portion of the load & P_2 the remaining load, the percentage of the additional load due to the centrifugal force related to the free vibrations is :

$$100\,\frac{2c}{wL}\left[f\,P_1 + P_2\right]$$

* Vide note at bottom of pages 16 (1)

and including the effect of speed as per para 3 above, the percentage of increase will be :*

$$(16)\quad \boxed{I_2'' = \frac{100}{1-c} \times \frac{2c}{wL}\left[fP_1 + P_2\right]}$$

Here again the calculated results in tables (9) and (10) show that the impact on the Reinforced Cement Concrete Bridge is nearly 3 times smaller than for the Steel Railway Bridge.

5. The effects of the unbalanced weights of the locomotive wheels and the alternating action of the driving pistons.

In the case of railway bridges, in addition to the vibrations examined previously, the dynamic action is further aggravated by the independent centrifugal forces arising from the rapid rotation of the unbalanced weights of the driving and coupled wheels of the locomotives as well as in certain cases by the vertical periodically alternating reactions of the connecting rods on their guides; this effect is usually called the hammer-blow.

It is true that the important eccentric loads of the spindles, crank shafts and connecting rods are balanced to a great extent by the additional counter weights cast on the locomotive driving and couplet wheels; this balancing is not, however, complete and there remains always a centrifugal resultant action which alternately intensifies and relieves the effect of the static loads on the bridge. In addition to the vertical forced vibrations these unbalanced weights being at right angle in the two wheels of the same axle, they produce a periodically alternating torque perpendicular to the axis of the bridge.

When the number of revolutions of the driving and coupled wheels is the same as the frequency of the free vibrations of the bridge intense resonance effects are possible.

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* In para 3 above, when estimating the effect of speed of the moving load, the intensity of the load has been taken equal to P.

In para 4, however, it has been shown that the centrifugal action increases the intensity of the live load to $P\left[1 + \frac{pc^2}{w} + \frac{2c}{wL}(fP_1 + P_2)\right]$

Consequently the effect of the speed, as estimated in para 3 for the basic live load P, should be extended also to its increments arising from the centrifugal action

Since according to formula (6a) the maximum dynamic deflection equals $\frac{1}{1-c}$ times the maximum static deflection in the centre of the beam, similarly the percentages of increase $100\frac{p}{w}c^2$ and $100\frac{2c}{wL}(fP_1 + P_2)$ arising from the centrifugal action should be multiplied by $\frac{1}{1-c}$ in order to include the effect of speed.

Hence the values : $I_2' = \frac{100}{1-c}\left(\frac{p}{w}\right)c^2$

and $I_2'' = \frac{100}{1-c}\frac{2c}{wL}(fP_1+P_2)$

given in formulae (14) and (16).

In practice, however, the effect of this type of vibration is not found as high as given by certain simplified calculations. In many tests carried out on lately built Steel Railway Bridges the counter effect of other impressed vibrations such as the rail joint effect and the simultaneous action of the other axle loads as well as the damping action due to the internal friction of the structure, the rigidity of the joints etc., have been found so important as to reduce to a practically negligible minimum the action of the independent centrifugal forces.

The problem of the hammer-blow impact on Steel Railway Bridges has received considerable attention by the British Engineers since the publication of the Report of the Bridge Stress Committee in 1928 and a number of very interesting papers dealing with the subject have been read in the last few years before the Institution of Civil Engineers. As the calculations evolved would be too lengthy to reproduce in this paper, a reference is made to the conclusions reached by Messrs. R. W. Foxlee & E. H. Greet in their paper entitled "Hammer Blow Impact on the Main Girders of Railway Bridges". * It may be noted also that the final formulæ established by the Authors are recommended for the calculation of hammer-blow impact by the British Standard Specification No. 153 Parts 3, 4, & 5 of 1937.

Taking :

(1) The hammer-blow of the whole locomotive as 0.2 T at 1 revolution per second of the driving wheels.

(2) The maximum speed as 6 revolutions per second (with a wheel diameter of approximately 5′-3″ this would give a lineal speed of 100 feet per second).

(3) The maximum values specified for the constant coefficients included in the formulæ.

The hammer-blow impact is given as follows :

For spans upto 40 feet :

$$(17)\ I_s = 100 \times \frac{1.25 \times 25 \times 0.2}{U} \times \frac{6}{L+40} = \frac{225}{U} \times \frac{100}{L+40}$$

For spans over 40 feet and upto 80 feet.

$$(18)\ I_s = 100 \times \frac{0.45 \times 25 \times 0.2}{U}\left(1+\frac{L-40}{25}\right) = \frac{225}{U}\left(1+\frac{L-40}{25}\right)$$

For spans over 80 feet and upto 300 feet..

$$(19)\ I_s = \frac{225}{U} \times \frac{390}{L+70}$$

* Min: of Proc: of the Institution of Civil Engineers, London Volume 237, Paper No. 4896.

where L is the span in feet and U the number of units of British Standard Loading for which the Bridge is to be designed.*

The number of units of British Standard Loading approximately equivalent to the H. M. Standard of 1926 are :

U = 23 for the span of 10 feet.

U = 25.5 „ „ „ „ 20 feet.

U = 28 for all greater spans.

With the above values of U the hammer-blow impact for the Steel Railway Bridge considered in this paper, is given in the attached table No. 11. It will be seen from this table that the impact percentage in this case does not decrease steadily when the span is increasing ; the spans around 100 feet are affected almost to the same extent as a span of 10 feet.

6. The effect of rail joints, defective wheels or uneven road surfaces

As mentioned at the beginning of Part II of this paper, the sudden application of a load on a beam produces theoretically the double of the static deflection. If the load actually drops on the beam from a certain height the deflection is nearly proportional to the square of the drop, it can be easily seen that for any bridge should a similar condition of impact ever materialise, with the actual intensity of the axle loads, even for very small drops, the deflections would be such as to exceed in every case the limits of safety.

Fortunately the actual conditions of impact met with in practice differ materially from the ideal conditions of perfect impact for which the above conclusions are drawn The suspension springs of the vehicles limit the impact load to a small fraction of the total axle load Further the elasticity of the materials affected by the impact reduces the intensity of the shock to such an extent that the observed increase in stresses is several times smaller than the theoretical values.

On Road Bridges a real shock can never be expected firstly because the wearing surface forms an elastic mattress absorbing the major part of the kinetic energy and secondly because the loads and their speed of movement are not sufficient to approach the conditions of a sudden drop when an obstacle or a pot hole is overrun Heavy and at the same time, fast moving vehicles, it should be remembered, are always fitted today with efficient springing arrangements, and pneumatic or thick solid rubber tyres, which hinder the shock to a great extent

* It will be noted that at the common limit of L = 10 feet formulae (17) and (18) do not give the same value of impact as it ought to be

The reason for this discrepancy is that in formula (17) the main girders are taken as supporting the rails directly, whereas formulae (18) and (19) are drawn for the case of main girders not directly supporting the rails, for these greater spans it is indeed common practice to space the main girders further apart than the rails themselves in order to increase the lateral stability of the bridge and keep the level of the rails low.

When the rails are not directly supported by the main girders in spans less than 10 feet the values given by formula (17) could be reduced by the factor 0.8 and the hammer blow impact on a 40 feet span would be in this case $\frac{445}{11}$, the same as obtained from formula (18).

For the Railway Bridges the cushioning effect is reduced to a minimum while on the other hand the intensity of the shocks is considerably aggravated through the regularity of the rail joints and the occasional local flattening of the wheel tyres, as shown on figure 3, caused by the slipping following a too hard brake action. It is clear that every time such a flat portion comes in contact with the rail there will be a shock which, owing to the speed, will produce more severe effects than the stationary load of the wheel dropping from a height equal to the rise of the defective tyre segment. With heavy locomotive axles weighing 20 tons and over, running on short spans of comparatively small dead load, such an impact may become dangerous. However, such defective wheels are quickly detected on a well maintained line and they are removed from circulation well before their action becomes dangerous

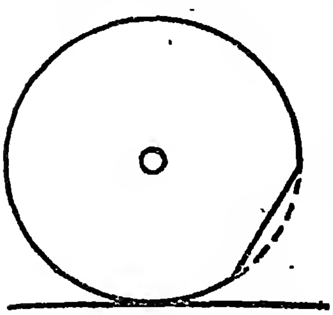


Fig. 3

Somewhat similar is also the effect of the rail joint impact. When the wheel approaches a joint, the loaded portion of the rail sinks and on account of the fishplate, it takes with it the adjacent rail portion. As shown on figure 4, the two rail pieces form at the joint an angle which is the cause of the impact. A single rail joint on the span of the bridge will produce free vibrations which will die out quickly. Successive rail joints, however, spaced at regular intervals, as is generally the case for the medium and long spans, will induce forced vibrations with a consequent possibility of dangerous resonance effects. The importance of well designed fish plates allowing for a very rigid connection, and the minimum possible play at the joint can be judged from these considerations; welded joints over the whole length of a bridge may reduce the impact by over ten per cent.

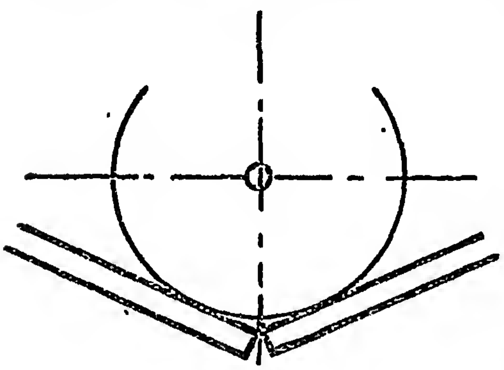


Fig 4

It has been argued sometimes that forced vibrations similar to those due to successive rail joints may occur on road bridges also, when the wearing surface is damaged and covered with potholes; this, however, is incorrect. Even overlooking the fact that loads moving on a damaged road surface will necessarily keep to a very low speed, it should be remembered that the irregular spacing of the pot-holes brings a favourable distributing action on the resulting forced vibrations; the successive shocks occuring at varying time intervals are mostly antagonistic in their effects and all possibility of resonance is excluded for these road bridges.

An adequate method for the calculation of this type of dynamic increment is not yet available, but both theory and experiments lead to the conclusion that this part of the impact is directly proportional to the ratio of impacting to impacted mass *i. e.*, in this case the ratio of live load to dead plus live load of the bridge.

From the experimental data available from tests on Steel Railway Bridges the formula recommended by the British Standard Specification No. 153 parts 3, 4, and 5, 1937 appears quite satisfactory for the estimation of the impact due to track irregularities on Steel Railway Bridges.

For the maximum effects the impact percentage factor is :

$$\boxed{I_1 = \frac{100 \times 180}{(L+20)\,U}} \qquad (20)$$

where again L is the span in feet and U the number of units of British Standard Loading for which the bridge is to be designed. With the values of U given in para 5 above, Table No. 12 gives the impact values for the Steel Railway Bridge.

Following the principle stated above the impact percentages for the Reinforced Cement Concrete Road Bridge may be found readily by multiplying by the factor :

$$\frac{p'}{w'+p'} \times \frac{w+p}{p} = \frac{1+w/p}{1+w'/p'}$$

the values given by the above formula (20) for the Steel Railway Bridge. In this factor, w and p are respectively the dead and live load for the Steel Railway Bridge and w′ and p′ the same loads for the Reinforced Cement Concrete Road Bridge as given in tables Nos. 1 and 2.

The calculated impact percentages due to surface irregularities for the Reinforced Cement Concrete Road Bridge are finally given in the attached Table No 13.

PART III.

CONCLUSIONS :

In the foregoing part an attempt has been made :

(a) to review briefly our present knowledge of Bridge Dynamics in its practical aspect,

and (b) to apply the theoretical procedure to the calculation of the impact effects of moving loads.

The general formulæ established for each of the component parts of the dynamic action have been finally applied to the two cases of a Single Track Steel Railway Bridge and a Single Lane Reinforced Concrete Road Bridge; the calculated total impact percentages for the various spans are summarised for each case respectively in the attached Tables Nos. 14 and 15.

That the method is consistent, complete and simple enough to be used in actual designing practice is, I think, fairly well established. There remains, however, a last but very important question to be answered and that is "how far are the impact factors derived by this method reliable and representative of the actual facts ?" The necessity of answering this question is characteristic of all theoretical methods. In order to enunciate the problem in its general form and to render it accessible to mathematical analysis, a theory has to set out from a number of simple principles assuming almost ideal conditions which, however, very seldom appear in the first instance as being in complete agreement with the conditions actually met with in practice. To remove this doubt the best way and the only one generally considered as satisfactory from the Engineer's point of view, consists in applying the theory to one particular practical example accessible also to a direct experimental test and comparing the results thus obtained under the same conditions by the theoretical and the experimental procedure. Should the theoretical results coincide or at least reasonably approximate those directly obtained by the test, it can be usually accepted that the fundamental principles of the theory adequately cover the actual practical conditions and the theory is confirmed for general use,

Since practically all impact experiments carried out upto now have been limited to Steel Railway Bridges only, the test case for the Impact Theory, explained in the Second Part of this paper, will have to be taken for the Single Track Steel Railway Bridge. From the experimental impact results available for comparison, there cannot be a better choice than the Indian Railway Board impact formula (3)

$$I = \frac{65}{45+L}$$

which represents a reliable and fairly close interpretation of the impact tests carried out on the Indian Steel Railway Bridges by the Railway Bridge Standards Committee.

The impact percentages obtained from this formula are given in the penultimate line of Table No. 14 and the comments on the comparison are as follows :—

For the smallest span of 10 feet, the theoretical impact percentage is almost 50 per cent higher than the experimental, and this is mainly due to the excessive values found for the impact component related to the

Centrifugal Force. There is, however, a good reason to doubt the reliability of these values for such a small span. It may be recalled that failing an accurate solution of the differential equation (11) in para 4 part II above, an approximate method has been adopted. This approximation however, is good only when the inertia factor $\frac{1}{g}\times\frac{V^2}{R}$ is small compared to 1—that is when the dynamic increment is small compared to the live load itself—yet the results found for the 10 feet span give an impact 89.4 per cent of the live load which is incompatible with the above condition. As in any case the total impact cannot exceed 100 per cent of the live load, this value may be substituted in preference to the calculated percentage of 149.1 for the span of 10 feet.

For the spans between 20 and 100 feet, the theoretical values remain considerably lower than the experimental ones. This is due on one hand to the rather high values accepted in the experimental formula for the hammer blow impact for these medium spans and on the other hand to the fact that the theoretical values do not allow for lurching or transversal vibrations.

The question of the hammer blow impact on medium spans has been extensively discussed in the last reports of the Railway Bridge Standards Committee and although small impact percentages have been recorded on several tests on these medium spans, the Committee decided at the time that these tests were unreliable and pending further investigations on the subject, they preferred to err on the side of safety. It is, however, now conceded that the smaller impact values for medium spans are more plausible.

Regarding the lurching effect, this has been purposely excluded from the theoretical calculations as its effects are limited only to the rail bearing girders and should be accounted for separately.

With the formula for lurching given in the British Standard Specification No. 153 Parts 3, 4 and 5, 1937 the impact percentages in the case of the Single Track Steel Railway Bridge are:

Span L in ft.	10	20	30	50	70	100	150	250	400
Lurching Impact percentage.	18.2	16.7	15.4	13.35	11.75	10.0	8.0	5.4	4.0

If now—in order to bring the theoretical impact percentages to the same basis for comparison with the impacts given by the formula $\frac{65}{45+L}$, the lurching effects calculated above are added and the hammer blow impacts I, for all spans between 10 and 70 feet are kept with the maximum value of 19.6 per cent, the amended theoretical impact percentages are given in the following Table against the corresponding experimental values obtained from the formula $\frac{65}{45+L}$:

Span L in ft.	10	20	30	50	70	100	150	250	400
Theoretical Impact	100.0	98.7	77.5	61.8	53.5	46.1	35.9	26.0	18.5
Experimental Impact (formula $\frac{65}{45+L}$)	100.0	100.0	86.7	68.4	56.6	44.8	33.4	22.0	14.5

It will be seen from this table that the agreement between the tests and the theory is very satisfactory.

At this stage it may be of interest to mention here the present French Impact Formula:

$$I = \frac{0.4}{1+0.2L} + \frac{0.6}{1+4\frac{w}{p}}$$

(L = span in meters ; w = dead load ; p = live load)

which is the first official formula to break away from the tradition of making the impact dependent on the span only. With 60 per cent of the total impact varying with the ratio of dead to live load this formula constitutes a remarkable attempt to do away with empirical methods and combine simplicity of form to a closer interpretation of the actual dynamical facts. The values obtained from this formula for the Steel Railway Bridge and the Reinforced Concrete Road Bridge considered in this paper, are given in the last line of tables Nos. 14 and 15 respectively and the agreement with the theoretical values is very good, particularly in the case of the Reinforced Cement Concrete Road Bridge.

In table No. 15, penultimate line, the values given by the Indian Roads Congress impact formula are given for comparison and it will be seen that for the Reinforced Cement Concrete Road Bridge for all spans upto 100 feet these values are more than 100 per cent higher than the theoretical values or those given by the French Formula.

For the same reasons as stated above, in the case of the Steel Railway Bridge, the total theoretical impact percentage given in table No. 15 for the 10 feet span is unreliable and as such it is shown in brackets.

On the strength of the above comparisons a revision of the present Indian Roads Congress impact formula, when applied to Reinforced Cement Concrete Road Bridges, can be claimed as entirely justified. In order to avoid complications it is suggested that a clause may be inserted in the present Indian Roads Congress Code allowing a 50 per cent reduction in the impact values obtained by the present Indian Roads Congress impact formula when applied to Reinforced Cement Concrete Road Bridges for all spans above 20 feet, with the limitation of 30 per cent impact for a 20 feet span and 50 percent impact for a 10 feet span, the variation of the impact between these two spans being lineal. With this amendment the proposed impact values for Reinforced Cement Concrete Road Bridges are given in the following table together with the theoretical impacts obtained in table No. 15 and the values given by the French Formula for comparison:

Span L in ft.	10	15	20	30	40	50	60	70	80	100
Proposed impact from amended I. R. C. Formula.	50.0	40.0	30.0	21.7	19.1	17.1	15.5	14.1	13 0	11.2
Theoretical impact.	50.0	41.1	32.3	20.8	16.1	13.6	12.2	11.2	10.7	10.0
Impact from French Formula.	48.2	39.4	31.1	23.0	18.0	14.6	12.2	10.4	9.0	7.1

While the foregoing evidence in favour of the proposed lower impact percentages for Reinforced Concrete Bridges can be claimed as convincing

enough, there are further good reasons for considering the theoretical impact percentages calculated above as still being well above the possible actual acceptable values.

In the absence of reliable numerical data concerning the internal frictional resistance of the structures, the resulting damping action on the dynamical vibrations has been altogether neglected in the foregoing theory. It is however known that the internal frictional resistance increases with the speed of the vibrations and its effect is to convert the motion energy into heat energy thus diminishing constantly the amplitude of vibrations.

Although accurate values of the friction co-efficients of steel and concrete structures are difficult to obtain a fairly reliable and conservative estimation proves that concrete has a friction coefficient about seven times higher than steel. As the damping action varies in proportion to $e^{-\frac{1}{2}kt}$ (where e = Napierian base, k friction coefficient and t the time) the damping effect in concrete structures is, therefore, equal to the damping effect in the steel raised to the seventh power.

Finally, bearing in mind that the determination of the impact coefficients in the design of a structure directly affects its factor of safety, it will not be out of place here to mention also that the ratio of dead to live load, which has proved a decisive factor in the effects of the dynamic action of the live loads, has also a predominant direct influence on the effective factor of safety for these same live loads.

With the actual designing practice of determining the safety factor by the ratio of working stresses to the breaking stresses for concrete or yield point stresses for steel, the same apparent factor of safety seems to be accepted both for the dead and live load. It is, however, much more reasonable to fix a lower factor of safety for the dead loads which can be accurately estimated and are not liable to any future variation, and a higher factor of safety for the live loads which at the time of designing are more or less hypothetical and may actually prove in the course of time considerably higher than originally estimated.

Let w = dead load, p = live load, f the selected factor of safety for the dead loads, F the factor of safety for live loads and R the apparent total factor of safety which is equal to the ratio of working to breaking stresses.

The relation between these values is:

$$w \times f + p \times F = R\ (w + p).$$

and $$F = (R - f)\ \frac{w}{p} + R.$$

proving that the actual factor of safety for live loads depends on the ratio of dead to live load and increases as this ratio is increased. Assuming $R = 2.5$ and $f = 1.5$ and taking p as the Indian Standard Loading (or its equivalent uniformly distributed as worked out in the third line of table 2) both for Steel and Reinforced Cement Concrete Road Bridges, assuming also that the dead load of a Steel Road Bridge will be approximately the same as for a Steel Railway Bridge, the ratio of the actual factors of safety

for the live loads for the same Bridge constructed in one case in Reinforced Concrete and in the other case in Steel is:

$$\frac{F_c}{F_s} = \frac{\frac{w'}{w} + \frac{R}{R-f} \times \frac{p}{w}}{1 + \frac{R}{R-f} \times \frac{p}{w}}$$

where w' = dead load for the Reinforced Cement Concrete Bridge
w = dead load for the Steel Bridge.

The values of the ratio $\frac{F_c}{F_s}$ are given in the table below:

Span L in ft.	10	20	30	50	70	100
$\frac{F_c}{F_s}$ =	1.09	1.19	1.295	1.36	2.1	3.12

and it will be seen that the Reinforced Concrete Bridge can actually carry a live load varying from 10 per cent for the 10 feet span, to 212 per cent for the 100 feet span, greater than the Steel Bridge and with the same factor of safety.

The paper is accompanied by 15 Tables and one Graph

TABLE 1

Natural vibration frequency of a Single Track Steel Railway Bridge.

Span L in ft.	10	20	30	50	70	100	150	250	400
Dead load w in tons	0.30	0.35	0.40	0.50	0.60	0.75	0.90	1.20	1.50
Live load p in tons	5.81	5.26	5.10	4.29	3.91	3.55	3.43	3.14	2 88
Dead + live load in tons	6.11	5.61	5.50	4.79	4.51	4.30	4.33	4.34	4.38
Bending moment in ft. tons	76.4	281	618	1496	2760	5375	12180	33900	87600
Depth of girder : h in ft.	1	2	3	5	7	10	15	25	40
Max. Allowable stress : t	8 tons/sq. inches = 1152 tons/sq. foot								
Moment of inertia ; I	0.033	0.244	0.804	3.25	8.38	23.3	78.8	368	1520
Modulus of elasticity	E = 30 × 10⁶ lbs./sq. inch = 1.93 × 10⁶ tons/sq. foot								
Acceleration of gravity	g = 32.2 feet/sec./sec.								
Natural frequency : n_1	41	26	19 5	12.6	9.5	6.9	5.2	3.5	2.5

Note :—

Bending moment $M = (w + p)\dfrac{L^2}{8}$

Moment of inertia $I = \dfrac{Mh}{2t}$

Natural frequency $n_1 = \dfrac{\pi}{2L^2}\sqrt{\dfrac{gEI}{w}}$

TABLE 2

Natural vibration frequency of a Single Lane R. C C. Road Bridge.

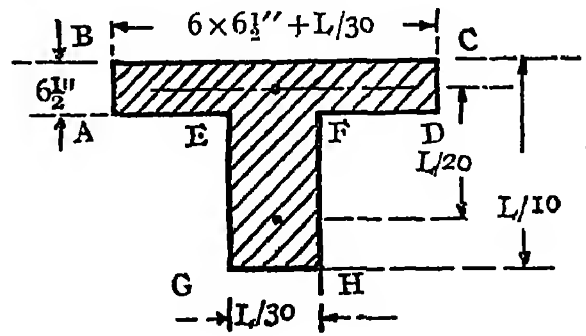
Span L in ft.	10	20	30	40	50	60	70	80	100
Dead load w in tons	0 74	0 86	1.06	1.34	1 70	2.14	2 66	3 26	4.70
Live load p in tons	1 88	0.94	0.74	0.64	0.58	0 54	0 51	0 49	0.46
Dead + live load in tons	2.62	1.80	1.80	1.98	2.28	2.68	3 17	3.75	5.16
Bending moment in ft. tons	32 7	90.0	203	396	712	1206	1941	3000	6450
Depth of main girder	1	2	3	4	5	6	7	8	10
Moment of inertia . I	0 172	1 9	8 0	22.2	49.4	95.0	167	273	631
Modulus of elasticity	$E=3\times10^6$ lbs./sq. inch $= 1.93\times10^5$ tons/sq. foot								
Acceleration of gravity	g=32.2 feet/sec/sec.								
Natural frequency : n_1	19	14 6	12.0	10 0	8.5	7.2	6.3	5.6	4 5

Note:—

Bending moment $M = (w'+p')\dfrac{L^2}{8}$

Moment of inertia $I = I_1 + I_2 + \dfrac{A_1 \times A_2}{A_1 + A_2}\left(\dfrac{L}{20}\right)^2$

Natural frequency $n = \dfrac{\pi}{2L^2}\sqrt{\dfrac{gEI}{w}}$



A_1 = area ABCD
A_2 = ,, EFGH

TABLE 3

Impact due to the speed of moving loads on a Single Track Steel Railway Bridge.

Span L in ft.	10	20	30	50	70	100	150	250	400
Speed v in ft. / sec.	100 ft. / sec.								
Coefficient $c = \frac{v}{2Ln_1}$	0.122	0.096	0.086	0.080	0.075	0.072	0.064	0.057	0.05
Dynamic percentage factor I_1 ..	14	10.6	9.4	8.7	8.1	7 8	6.8	6.0	5.3

TABLE 4

Impact due to the speed of moving loads on a Single Lane R. C. C. Road Bridge.

Span L in ft. ..	10	20	30	40	50	60	70	80	100
Speed v in ft. / sec.	75 ft / sec.								
Coefficient $c = \frac{v}{2Ln_1}$ ..	0.198	0 129	0.105	0.094	0 089	0.087	0 085	0 084	0 083
Dynamic percentage factor I_1 ..	24 7	14.8	11.75	10.4	9.8	9 5	9.3	9.2	9.1

TABLE 5

Reduction Coefficient f due to the springs for Single Track Steel Railway Bridge.

Span L in ft.	10	20	30	50	70	100	150	250	400
Spring frequency n'	2.5								
Natural frequency of the Bridge n_1 ..	41	26	19.5	12 6	9.5	6.9	5.2	3.5	2.5
Reduction factor f	0.0037	0.0093	0.0173	0.042	0.074	0.15	0.30	1	1

TABLE 6

Reduction Coefficient f due to the springs for a Single Lane R. C. C. Road Bridge.

Span L in ft.	10	20	30	40	50	60	70	80	100
Spring frequency n'	2.5								
Natural frequency of the Bridge n_1 ..	19	14.6	12	10	8.5	7.2	6.3	5.6	4.5
Reduction factor f	0.0176	0.030	0.045	0.067	0.094	0.136	0.186	0.248	0.45

TABLE 7

Impact due to the centrifugal action of the moving loads on a Single Track Steel Railway Bridge.
Part of the forced vibrations.

Span L in ft.	10	20	30	50	70	100	150	250	400
Ratio of live to dead load : p/w ..	19.4	15	12.75	8.6	6.5	4.73	3.81	2.62	1.92
Dynamic coefficient c	0.122	0.096	0.086	0.080	0.075	0.072	0.064	0.057	0.05
Dynamic percentage factor $I_2' = \frac{100}{1-c} \times \frac{p}{w} \times c^2$ ..	(33)	15.3	10.3	6.0	4.0	2.6	1.67	0.90	0.5

TABLE 8

Impact due to the centrifugal action of the moving loads on a Single Lane R. C. C. Road Bridge.
Part of the forced vibrations.

Span L in ft.	10	20	30	40	50	60	70	80	100
Ratio of live to dead load : p/w ..	2.54	1.09	0.70	0.48	0.34	0.25	0.19	0.15	0.10
Dynamic coefficient c ..	0.198	0.129	0.105	0.094	0.089	0.087	0.085	0.084	0.083
Dynamic percentage factor $I_2' = \frac{100}{1-c} \times \frac{p}{w} \times c^2$ ..	(12.45)	2.08	0.86	0.47	0.30	0.21	0.15	0.12	0.08

TABLE 9

Impact due to the centrifugal action of the moving loads on a Single Track Steel Railway Bridge.
Part of the free vibrations.

Max. axle load = 28 tons

Part of the load on springs $P_1 = 0.80 \times 28 = 22$ tons.
Directly impacting load $P_2 = 0.20 \times 28 = 6$ tons.

Span L in ft.	10	20	30	50	70	100	150	250	400
Ratio of Max. impacting to impacted load: $\frac{fP_1 + P_2}{wL}$	2.03	0.89	0.53	0.28	0.18	0.124	0.093	0.093	0.47
Dynamic percentage factor $I_i'' = 100 \times \frac{2c}{1-c} \cdot \frac{fP_1 + P_2}{wL}$	(56.4)	18.9	10	4.9	2.9	1.9	1.27	1.12	0.5

TABLE 10

Impact due to the centrifugal action of the moving loads on a Single Lane R. C. C. Road Bridge.
Part of the free vibrations.

Max. axle load = 12 tons

Part of the load on springs $P_1 = 0.80 \times 12 = 9$ tons.
Directly impacting load $P_2 = 0.20 \times 12 = 3$ tons.

Span L in ft. . ..	10	20	30	40	50	60	70	80	100
Ratio of max. impacting to impacted load $\frac{fP_1 + P_2}{wL}$	0.43	0.19	0.107	0.067	0.045	0.033	0.025	0.02	0.015
Dynamic percentage factor $I_2'' = \frac{2c}{1-c} \times \frac{fP_1 + P_2}{wL}$	(21.25)	5.62	2.51	1.40	0.88	0.63	0.47	0.37	0.27

TABLE 11

Hammer Blow Impact on a Single Track Steel Railway Bridge.

(In accordance with the formula recommended by the B. S. S. No. 153, parts 3, 4 and 5 of 1937).

Span L in ft.	10	20	30	50	70	100	150	250	400
No. of units B. S. L. equivalent to H. M. Standard Loading of 1926.	23	25 5	28	28	28	28	28	28	28
Hammer-blow impact I_1	19.6	14.7	11.5	11.3	17.7	18 5	14.3	9.8	6.7

TABLE 12

Impact due to the Track Irregularities on a Single Track Steel Railway Bridge.

Span L in ft.	10	20	30	50	70	100	150	250	400
No. of units B. S. L. equivalent to H. M. Standard Loading of 1926.	23	25.5	28	28	28	28	28	28	28
Impact due to the track irregularities I_t	26.1	17.6	12.8	9.2	7.1	5 3	3.8	2.5	1 5

TABLE 13

Impact due to the surface irregularities on a Single Lane R. C. C Bridge.

Span L in ft.	10	20	30	40	50	60	70	80	100
Reducing factor depending on the ratio of dead to live loads: $\left\{ \begin{array}{l} 1+w/P \\ 1+w'/P \end{array} \right.$	0 756	0.557	0.444	0.354	0.284	0.229	0.185	0.153	0.108
Impact due to surface irregularities: I_t	19 8	9.8	5.7	3.79	2.61	1 84	1.32	0.98	0 57

TABLE 14

Total Impact on a Single Track Steel Railway Bridge.

Span L in ft.	10	20	30	50	70	100	150	250	400
Impact due to speed I_1	14.0	10.6	9.4	8.7	8.1	7.8	6.8	6.0	5.3
Impact due to the centrifugal action (forced vibrations) I_2'	(33.0)	15.3	10.3	6.0	4.0	2.6	1.7	0.9	0.5
Impact due to the centrifugal action (free vibrations) I_2''	(56.4)	18.9	10.0	4.9	2.9	1.9	1.3	1.1	0.5
Impact due to the hammer-blow I_1	19.6	14.7	11.5	11.3	17.7	18.5	14.3	9.8	6.7
Impact due to the tract irregularities I_1	26.1	17.6	12.8	9.2	7.1	5.3	3.8	2.5	1.5
Total Impact	(149.1)	77.1	54.0	40.1	39.8	36.1	27.9	20.3	14.5
Impact in accordance with Formula $\frac{65}{45 + L}$	100 (118.0)	100	86.7	68.4	56.6	44.8	33.4	22.0	14.5
French formula	75	65	60	51	45	39	33	26	16

TABLE 15
Total Impact on a Single Lane R. C. C. Road Bridge.

Span L in ft.	10	20	30	40	50	60	70	80	100
Impact due to speed I_1	24.70	14.80	11.75	10.40	9.80	9.50	9.30	9.20	9 10
Impact due to the centrifugal action (forced vibrations) I_2'	12 45	2.08	0 86	0 47	0.30	0.21	0.15	0.12	0.08
Impact due to the centrifugal action (free vibrations) I_2''	21.25	5 62	2.51	1.40	0.88	0.63	0.47	0.37	0.27
Impact due to surface Irregularities I_3	19.80	9.80	5.70	3.79	2.61	1.84	1.32	0.98	0.57
Total Impact	78.20	32.30	20.82	16.06	13.59	12.18	11.24	10.67	10 02
I. R. C. Formula	50.0	50.0	43.35	38.25	34.2	31.0	28.3	26.0	22.4
French Formula	48.2	31.10	23.03	18.00	14.63	12.18	10.36	8.96	7.08

DISCUSSIONS ON PAPER L—39.

Mr. E. P. Nicolaides (Author) :—In introducing my paper I feel I must first apologise for having been so late in submitting it for your scrutiny.

When I first tackled the subject at the instigation of Mr. Nilsson, my object was to make a comparative statement of the impact formulæ in use in the various countries, with the purpose of finding out how far the Indian Roads Congress Impact formula is in agreement with the practice adopted outside India on this important subject. The more I went on with this programme, however, the more I found that no useful conclusions could be drawn from such a work, owing to the fact that the majority of countries today still accept for use old empirical impact formulæ which have neither experimental nor theoretical justification and the results of which diverge widely from one country to the other.

At this stage, although I had already lost valuable time, I decided that in order to set forth something worth reading, I had no other alternative but to change my programme.

Thus I proceeded :—

Firstly to review and discuss the foundations of the present Indian Roads Congress formula; this is done in part I of the paper.

Secondly to set forth a rational method based on our present theoretical knowledge of bridge Dynamics, with a view to use this method for comparing with the results obtained by the Indian Roads Congress formula; this has been attempted in part II of the paper. I may mention here that the adoption of the theoretical method for comparison has not been a matter of personal choice but an unavoidable necessity imposed by the deficiency of our present experimental knowledge of the impact on bridges.

On the other hand the difficulties arising from the theoretical method had to be carefully weighed. Many practical Engineers are inclined to be distrustful of the results obtained through complicated mathematics, but such an attitude is seldom justified. Correctly used and adequately interpreted without losing sight of the practical aim at stake, the mathematical deduction offers to the Engineer a powerful and infallible means for the solution of his problems; through the exclusion of all doubtful or uncertain arguments in the process, the results are bound to be correct, provided the practical working conditions of the case under consideration adapt themselves well to the universally accepted mathematical and mechanical principles and laws.

The theoretical method, developed in the second part of this paper, is based on the partial differential equation of the transverse vibrations of an elastic beam; the methods of solving this equation have been summarily stated in the paper and could be further amplified, if necessary, by referring to the works of their original authors. Where used, approximations or other simplifications have been analysed and their accuracy has been checked at the end.

Thus the one and only point remaining to be proved, in order to establish the adequacy of the method from the practical point of view, is whether an actual Bridge Girder conforms to the theoretical definition of an Elastic Beam

That this conformity exists as far as the static action of the loads is concerned is, of course, a fact on which have been based all our designs of bridges or other structures upto now. On the strength of this assertion it would appear more than plausible to identify a Bridge Girder to an Elastic Beam, also when the action of the loads is dynamic.

From the third and last part of the paper you will see that I have, however, gone further than this. Making use of the experimental evidence available in the particular case of Indian Steel Railway Bridges, I have shown that the results of the theoretical method agree with the results of the tests carried out in this field.

To my knowledge, impact tests in Reinforced Concrete Bridges are not available. There is no reason, however, why the theoretical method, which has been proved correct in the case of Steel Railway Bridges, should not apply also to Reinforced Concrete Road Bridges. Such an application has been worked out in the paper and shows clearly that the feeling of many Specialist Engineers, who assert that the impact on Reinforced Concrete Structures is bound to be much less than in similar Steel Structures, is entirely justified. French Engineers, as I have mentioned in the paper, are the first to give official confirmation to this claim for lower impact percentages on Reinforced Concrete Bridges.

And now I think I can ask you whether you still consider it correct to maintain the same impact formula for Reinforced Concrete Road Bridges as for Steel Bridges in a modern Code such as the one sanctioned by this Congress in 1937!

Mr. P. V. Raju (Madras):—In discussing the hammer blow effects on road bridges on page 18 (l) of his paper, the author says that the real shock can never be expected on account of the wearing surface forming an elastic mattress and secondly the loads and their speed of movement are not sufficient to approach the conditions of a sudden drop when an obstacle or a pot-hole is overrun.

Cases are not uncommon of tram tracks laid on Reinforced Concrete bridges the wearing coat of which is laid over the floor slab without an elastic mattress to damp the impact. The rails are buried in the wearing coat of the bridge and sometimes the rag bolts are taken deeper into the floor slab itself. In such a case what would be the impact effect? Would it come under "free vibrations," "surface irregularities" or "hammer blow" effect? I should like the author to elucidate me on this point.

Mr. K. G. Mitchell (Government of India):—I do not propose to speak at great length on the subject. I do think that Mr. Nicolaides's paper is a very definite contribution, so far as I have been able to study it, to the subject. We will endeavour to examine

it thoroughly. The committee which is to revise our bridge specifications will re-consider the question of impact. Gentlemen, you will realise that for want of sufficient time at our disposal it is not possible to discuss the paper at a greater length in this meeting. We are all grateful to the author.

Mr. P. V. Chance (Central Provinces & Berar) :—I have only one remark to make and that is about the proposal to change the Impact formula in the Indian Roads Congress specification. I do not propose, or attempt to try to show that Mr. Nicolaides's calculations are wrong.

We at present allow for extraordinarily low loads. The knife edge load is negligible on long spans and need only be taken into account in calculating cross beams and the like The uniform load of 76 pounds a square foot was taken for foot-paths a few years ago and is still used for the floors of living rooms. You will no doubt say that if the loading is too light, the proper procedure is to increase the load and correct the impact formula. But we must have some factor of safety to allow for accidents which do not often occur on railway bridges but which are much more common on road bridges and it seems to me that it is more correct to allow for such unusual conditions in the impact formula. While, therefore, I do not mean to dispute the correctness of Mr. Nicolaides's theory, I think, we should have an adequate factor of safety in the impact formula to be used in the design of our bridges.

Dr. M. A. Korni (Calcutta):—A few years ago I read a paper on impact on bridges before the Institution of Engineers in which a comparative statement was made showing the striking difference of the effects in Bending Moments produced by a rolling load of the same magnitude under the same conditions when passing a steel bridge and a concrete bridge.

I assume that most of the members of the Roads Congress are members of the Institution of Engineers (India), and probably have read this paper with the exhaustive comments made by our friend, the late Mr. Radice. There is little left now for arguments to prove that the impact formula recommended by the Roads Congress is of any value; and moreover, firstly, when dealing with an imaginary term like a knife edge loading (knife loads do not roll) and secondly if this formula is to be applied to a real rolling load, we must always bear in mind the difference in dead load between a steel bridge and a concrete bridge. As explained in my paper on Impacts, by impacts is to be understood an accumulation of shocks causing vibration due to a moving load and thereby additional deflection. These vibrations are damped by the dead weights of the structure and it would be more reasonable to use the French formula of impact where the ratio between the dead load and live load of a bridge is taken into account.

The French formula is: $i = 1 + \dfrac{0.4}{1+0.2L} + \dfrac{0.6}{1+4\dfrac{W_d}{W_l}}$ where the subscripts W_d and W_l denote the dead load and the live load.

In steel bridges a certain amount of deflection in relation to its span is stipulated in the specification. This is a kind of check on the factor

of safety which the structure possesses. It would be advisable to recommend a similar ratio for a concrete bridge which should be not less than $Y = \frac{1}{6000\ L}$ where Y signifies the deflection and L the span.

It has been found that if a bridge, when tested with the designed load "w" shows a deflection $\frac{1}{6000\ L}$, a load "4w" will cause a failure to the bridge. Concluding my remarks concerning Impact, I am always prepared to serve the Congress with all necessary information about Impact that I may have in my possession.

Mr. D. Nilsson (Bombay):—At Hyderabad, in 1938, the Congress passed a Report by Council which recommended that "no further action need be taken to undertake the investigation into the question of impact". At the time I objected to this but I must now apologise for having wasted the Congress's time. The majority was obviously correct in passing this resolution as it was also obvious that if the Congress would do nothing in the matter somebody else would have to do it for them; and Mr. Nicolaides has done the work.

After the Hyderabad meeting, I suggested to Mr. Nicolaides that he should go into the question of the impact specifications of all the various countries and see whether there was not some justification for a different impact factor for Reinforced Cement Concrete bridges as compared to that for steel bridges Mr Nicolaides has gone much further than this and produced a very excellent and very interesting paper. It is regretted that this has not been put in your hands at an earlier date but that could not be helped

I trust that nobody has been put off reading the paper by the appearance of the various formulæ The general arguments in the paper can reasonably be followed even without understanding the formulæ In thus suggesting that you. on account of the little time given, skip the formulæ, I do not by any means mean that you should just take them for granted and not later check them up. I find that there is much too often the tendency to assume that everything found in black and white is bound to be correct; if it was so I think we should not have so many different technical books all dealing with the same subject. I very often find that Engineers produce various books to prove that such and such is correct or that something else is wrong whereas in fact it very often turns out to be that the books are wrong. Therefore, I hope that those who can, will check the formulæ and if they find anything wrong, add to the discussion by written communications

As regards the formulæ in this paper, however, I would say that they are all based on standard formulæ which can be proved and in the mean time may be taken as correct

The result of the paper is to show that the Indian Roads Congress impact formula, which is based on the impact of railway trains on steel bridges, gives impacts which are double those that actually occur on Reinforced Cement Concrete bridges. This is confirmed by the French formula for impact which allows for the ratio of the dead load to the live

load and that ratio must obviously have a great effect on the impact. As you all know, the French are probably the most uptodate and have much the widest knowledge of reinforced concrete of any nation.

I wish to propose that the Indian Roads Congress Code be amended so that on page 10 after the word "formula" it will read :—

"For steel bridges :—

$$I=\frac{1}{2}\times\frac{65}{45+\frac{L(n+1)}{2}}$$ with a maximum value of 50 per cent.

For concrete bridges :—

$$I=\frac{1}{2}\times\frac{65}{45+\frac{L(n+1)}{2}}$$ for spans exceeding 20 feet, and equals 50 per cent for spans of 10 feet or less with a proportionate reduction to 30 per cent for spans of 20 feet".

Mr. E. P. Nicolaides (Author) :—Mr. Raju has mentioned the case of tram tracks directly fixed into the concrete surface of Road Bridges and he points out that in this case there is no elastic mattress to dampen possible vibrations. But when buried in the concrete, the tram rails do not present loose connections at their joints and consequently there is no impact attributable to rail joints or track irregularities. Hammer blow effect is also absent since there are no accentric weights on the tram car wheels. The only remaining impact effects are the effects of speed and centrifugal action; owing to the low speed generally attained by tram cars, these effects remain always small.

It is, of course, possible through mistake or negligence to get a joint out of level resulting in a sudden drop of the load at this point. Such a defective joint is bad for the tramway line, it is uncomfortable for the passengers using the tram cars, it is dangerous for the bridge carrying the tram line and should be corrected immediately on detection. In fact in the specification for a bridge carrying tram lines there should be always a clause forbidding such joints and it is not incumbent on the impact clause to cover such mistakes. The specification is a set of rules for a scientific technically sound design and a workmanlike correct execution of the bridge structure. It would lead to a vicious circle if one clause of this bridge specification, namely the impact clause, is drawn up to cover mistakes in design or construction carried out against the stipulations of other clauses of the same specification.

Somewhat similar considerations are raised by the remarks of Mr. Chance.

Mr. Chance considers the present Indian Roads Congress Standard Loading as extraordinarily low for long spans and he is of the opinion that the impact formula must provide for an adequate factor of safety to offset this deficiency. In many designs I have had the opportunity of making rough comparisons of the Indian Standard loading with other loadings specified by the various Indian Public Works Departments previous to the adoption of the Indian Roads Congress Code; in most of these comparisons the difference in the final results have been found unimportant. But if Mr. Chance is right in his criticism of the Indian Roads Congress Loading, I

maintain, it would be more to the point to amend the Loading clause of the Indian Roads Congress Code than to maintain a wrong impact factor.

It is difficult to detect and correct a wrong impact factor. A low live load, however, will be easily noticed and it is more than probable that it will be increased without reference to the impact factor. If, therefore, the impact factor is not corrected now, it can be anticipated that with increased live loads the designs will become even more unnecessarily expensive, wasting the tax-payer's money.

I may also mention in this connection, that the live load for which we have to design our bridges solely depends on the intensity and type of traffic anticipated over these bridges. But the impact factor is only a coefficient by which we have to multiply the live load in order to allow for the dynamic action of this live load. Besides its dependence on the live load itself, this dynamic action is mainly a function of the span, dead load, moment of intertia and elastic modulus of the bridge itself. It follows that even if both are designed for the same span, the same width of roadway and same live load, a Steel Bridge and a Reinforced Concrete Bridge will require different impact factors owing to their differences in dead load, stiffness and elastic modulus. The extent of this difference and the considerable advantages of Reinforced Concrete Road Bridges have been brought to light in the paper. If the same impact formula is kept for Steel and Reinforced Concrete Road Bridges, as Mr. Chance proposes, it would mean that Steel Road Bridges would have a live load carrying capacity and a final factor of safety considerably lower than Reinforced Concrete Road Bridges designed in accordance with the Indian Roads Congress Code; such a state of affairs would be both unscientific and irrational.

A lower impact formula for Reinforced Concrete Road Bridges, as proposed in my paper, would adjust the impact mainly in the lower and medium spans up to 100 feet; the difference being negligible in long spans for which Mr. Chance considers the Indian Standard Loading inadequate. Mr. Chance has also mentioned the possibility of accidents which, he considers, are more likely to occur on Road Bridges than on Railway Bridges. By accidents Mr. Chance means, I suppose, an abnormal action of the live load which is not ordinarily provided for in the designs. Such conditions are, however, well covered by the general factor of safety of the structures which is the ratio of breaking or yield point stresses to the maximum stresses allowed in the designs.

In this connection I would like to draw the attention of the Members of this Congress to the last para of my paper where without complicated mathematics I have shown that Reinforced Concrete Road Bridges as designed at present possess a considerable reserve of safety against the action of live loads which is non-existent on Steel Bridges.

Before I conclude, I wish to thank also Mr. Nilsson and Mr. Mitchell for the interest they have taken in the paper. I apologise again for the little time I have given you to study the paper; I hope that it will prove of interest to all Congress Members engaged in the design and construction of Road Bridges.

While correcting the proofs I had the opportunity to look into the question of the adequacy of the live loads specified in the Indian Roads Congress Code. On page 249 Appendix II of the Proceeding of the Third Meeting of Indian Roads Congress, Lucknow, Mr. W. A. Radice has given the actual train of lorries which is covered by the Indian Standard Loading. The train consists of a series of six wheeler 16 ton lorries each followed by two 8-ton trailers. Does Mr. Chance consider that heavier vehicles than these are likely to run over Indian Bridges?

Mr. G. P. Bhandarkar (Chairman): We are all very much indebted to Mr. Nicolaides for his valuable contribution. He considers the original steel bridge formula to be more or less empiric. He has gone into the question in a very scientific manner and the President has kindly agreed to place the matter before the Technical Sub-Committee of the Congress. As a result of this we expect that a revised formulæ would come out which would finally lead to economy in the construction of Reinforced Cement Concrete Bridges.

CORRESPONDENCE

Comments of Mr. S. B. Joshi, (Bombay).

The author is to be congratulated upon his paper on such an important subject as Impact factor on Road Bridges. There is a vast amount of literature dealing with the theoretical and the practical aspect of impact on Railway Bridges. But no serious attention has been paid to impact factor on Road Bridges. The author's plea is that impact factor on Road Bridges should be arrived at by rational analysis and that we should not blindly follow the Railway practice in this respect. The author has certainly made out a strong case for rational treatment of the subject and I think the Indian Roads Congress should set up a committee consisting of theoretical and practical Engineers to investigate the subject by taking observations on Bridges.

I will deal with some of the points arising out of the paper in the following remarks.

On page 3 (I), last para, the author quotes from the report of the Indian Railway Bridge Standards Committee, which states that 'the formula $\frac{65}{45+L}$ was admittedly constructed to cover impact on spans where resonance occurs, and on such spans it has a definite interpretative meaning'. This means an invariable rule that greater the span length less the effect of resonance. Theoretically such a statement is not correct. It has been ascertained theoretically that impact effects in main girders of Railway Bridges are most severe in Bridges of 100 to 120 feet span, having a natural frequency of about six, because synchronism occurs when the locomotives are moving at maximum speed. Impact formulæ of the Pencoyd type do not suggest any maximum impact effect for spans between 100 feet and 120 feet. It might be argued that the severe impact effects, theoretically found for spans between 100 to 120 feet, apply to conditions prevailing in England and that in India where 'higher critical speed' does not exist such severe impact effects for spans between 100 feet to 120 feet are not

experienced. But this is no argument for the perpetuation of the Pencoyd type of impact formula which has been theoretically proved to be incorrect. The author acquiesces in the Pencoyd type of impact formula presumably on the grounds of expediency. But it would have been much better if he had brought home the fact that the Pencoyd type of impact formula had no rational basis.

On page 6 (1), para 4, it is stated that load moving on a beam is not a suddenly applied load. This is because the ultimate stress is reached by gradual rise in the stress as the load moves from the support to the centre. There are, however, some exceptions to the statement, which should not be left unnoticed. The shear forces on a beam are suddenly applied loads. As a concentrated load moves past a point in a beam the shear force at the point changes sign with the result that the previous shear force is suddenly released and an opposite shear force is suddenly applied. Therefore the author's statement, that there are no sudden loads on a beam and consequently no excess stresses due to such sudden loads, is not correct as far as shear stresses (caused by a moving concentrated load) are concerned. Further even for stresses caused by bending moment, the load at the free end of a longitudinal cantilever in a cantilever bridge is a suddenly applied load. So also the loads coming on the end cross girders of bridges are suddenly applied loads. In such cases where the application of the load is wholly sudden the ultimate stress will be nearly double that due to a gradual load. In fact if the dead load of the beam is taken into account the stress due to a sudden load is given by

$f = f_{st} + \sqrt{f_{st}^2 + \frac{f_{st}^2 \times v^2}{g} \times \frac{1}{1\,\frac{17}{15} \times \frac{W}{P}}}$ where W is the dead load of the beam and P the live load, f the dynamic stress and f_{st} the static stress, and v the vertical velocity with which the load strikes.

The author has derived the expression for the impact coefficient due to speed by assuming the natural unloaded frequency of the girder. He has allowed for the inertia effect of the load by finding the excess load due to centrifugal force separately. It is a question why the author did not take effects due to speed and centrifugal force together in a single dynamical equation by taking the loaded frequency of the girder.

On page 14 (1), it is stated at the bottom that $\frac{100\ pc^2}{w}$ gives the percentage of the additional dynamic effect due to centrifugal force (forced vibrations). $\frac{p}{w}c^2$ is proved to be equal to $\frac{v^2}{gR}$. If a unit mass has a downward acceleration $\frac{V^2}{R}$ due to centrifugal force, naturally the extra load due to centrifugal force is $\frac{V^2}{gR}$. Therefore $\frac{V^2}{Rg}$ or $\frac{p}{w}c^2$ is itself the impact coefficient. The impact effect expressed as a percentage would be $\frac{100\ pc^2}{w}$. The author has expressed impact

effect as $\frac{100\ pc^2}{w\ (1-c)}$ saying that $(1-c)$ in the denominator relates to the static effect. It is difficult to imagine what further relation to static effects is necessary after finding the extra load per unit mass as $\frac{V^2}{gR}$.

It may be noted in passing that this coefficient $\frac{1}{1-c}$, used by the author, does not even tally with the coefficient $\frac{1}{1-c^2}$ given on page 11 (l). The extra load due to the centrifugal force is a load varying with the position of the load P, and it will not be correct to use even the coefficient $\frac{1}{1-c^2}$ for finding the dynamic effect of extra load due to centrifugal forces on the ground that $\frac{1}{1-c^2}$ expresses the dynamic effect due to the non-varying load P.

The same remarks apply to the denominator $(1-c)$ in the expression for the impact effect due to the centrifugal force (free vibrations).

On pages 16 (l) to 20 (l), the author deals with the impact effect due to hammer blow and track irregularities. Instead of finding these impact coefficients by the theoretical analysis, the author has taken resort to the formulae given in British Standard Specification No. 153 parts 3, 4 and 5.

Let us now examine the exact implications of the formulæ given in British Standard Specification No. 153 and which the author has used for finding the impact coefficients due to hammer blow and track irregularities.

British Standard Specification No. 153 gives in appendix (2) alternative methods of allowing for impact effects on Railway Bridges under sections I to IV.

Section III gives the Government of India impact formula $\frac{65}{45+L}$ and section I gives three formulæ :—

(*a*) Effects due to track irregularities $\frac{20\ kn}{(L+20)\ U}$ which is the same as the author's formula for I_4.

(*b*) Effects due to hammer blow the three formulæ being the same as the author's formulæ for I_5 given on page 17 (l).

(*c*) Effects due to locomotives with no reciprocating parts or multiple units. (*c*) is obviously an alternative to (*b*) and is to be used when there is no hammer blow as for Electric locomotives or for locomotives having multiple units.

It is claimed in British Standard Specifications that the results obtained by using section I agree closely with those obtained by the use of the Government of India formula $\frac{65}{45+L}$ given in section III, when due allowance for lurching is made.

This leads us to the following equation—

Results obtained by the use of British Standard Specification No. 153 App. 2 Sec.I $= \dfrac{65}{45+L}$,

$\therefore$ Sub-sec. (*a*) + Sub-sec. (*b*) of B. S. S. 153 App. 2 Sec I + Lurching effect $= \dfrac{65}{45+L}$

$\therefore$ The author's I_1 + Author's I_1 + Lurching effect $= \dfrac{65}{45+L}$ .. (I)

But the Author claims on pages 22 (l) and 23 (l) that the total theoretical impact found by him (*i.e.* $I_1+I_2+I_3+I_4$) after making due allowance for lurching agrees with $\dfrac{65}{45+L}$.

$\therefore$ $I_1+I_2+I_3+I_4$+Lurching $= \dfrac{65}{45+L}$ .. .. (II)

$\therefore$ From I & II

$I_4+I_3=I_1+I_2+I_3+I_4$.

Will the author explain the fallacy ?

Presumably the formulæ given in British Standard Specification No. 153—App. 2—Section I are covering formulæ which though given under two major heads *i.e.*, Track irregularities and Hammer blow, cover the effects due to all causes, otherwise the claim made in British Standard Specification No. 153, App. 2, section 1 that the results closely agree with the experimental covering formula given in section III, *viz.* $\dfrac{65}{45+L}$, will not be justified. Moreover, the British Standard Specification No. 153 does not give any other formulæ to allow foi speed and centrifugal force.

It is interesting to note that Mr. Foxlee, from whose paper the formulæ in British Standard Specification No. 153 are reproduced, compares his results with those obtained by the Indian Formula and does not make any mention of impact due to speed and centrifugal force (see discussion on Messrs. Foxlee & Greets' papers, Proceedings of the Institution of Civil Engineers, Vol. 237, pages 356, 357 & 358). This confirms the suggestion that the formulæ given by Mr. Foxlee and reproduced in British Standard Specification No. 153 are intended to cover all effects in addition to those of Hammer blow and Track irregularities and lurching. In fact Messrs. Foxlee and Greet claimed that their formulæ for Hammer blow effects were applicable to cases where there was no Hammer blow. On page 415 of the Proceedings of the Institution of Civil Engineers Vol. 237, Messrs. Foxlee and Greet in reply to Mr. Swain's contention observed that even if locomotive hammer blows were eventually reduced to zero, a contingency impact factor would still be required since they advocated the retention for purposes of computation of a maximum hammer blow value of 5 Tons at 5 revolutions per second (*i.e.*, 0.2 Tons at 1 revolution per second).

The author has found the value of Hammer blow impact by assumnig the hammer blow of the whole locomotive at 0.2 tons at 1 revolution per second. British Standard Specifications give 0.2 tons at 1 revolution per second as the least specified value, which according to the statement of

Messrs. Foxlee and Greet, referred to above, is to be assumed even in cases where there is no Hammer blow. Perhaps the author would say that, for Indian Railways and for the loading he has taken, the Hammer blow is less than 0.2 Tons at 1 revolution per second. But the author is comparing his results with the experimental formula $\frac{65}{45+L}$. Is it suggested that the formula $\frac{65}{45+L}$ holds good only for values of hammer blow below 0.2 tons at 1 revolution per second? I find that the curves drawn by Mr. Foxlee on page 338 of the 237th volume of the Proceedings of the Institution of Civil Engineers give a hammer blow of 0.765 tons at 1 revolution per second and 0.578 tons at 1 revolution per second, for standard I and standard II loadings. If these high values of hammer blow are taken the results given by the author, in his table 11 will have to be multiplied by 3 to 4 and the values obtained will upset his tables and calculations. It cannot also be seen why the author has used 23 to 28 B. S. units for his illustrations. Locomotives with less number of B..S. units would certainly give much higher value for the hammer blow than 0.2 tons at 1 revolution per second. In finding the impact coefficient due to hammer blow, he must take the worst case.

The author in dealing with impact due to track irregularities has used the formula $\frac{100 \times 180}{(L+20)U}$ given in British Standard Specification No. 153, App. 2 and says that impact due to track irregularities depends upon the ratio of live load to dead load plus live load. If the figures given in his table 12 are taken, it is found that the relation between the impact effect and the ratio of live load to live load *plus* dead load is not linear Will the author explain what exactly he means by saying that the impact effect depends upon the ratio $\frac{p}{p+w}$? The formula he has used for finding impact due to track irregularities does not contain any term involving the ratio $\frac{p}{p+w}$. In fact in the case of two Railway Bridges of the same span and having different ratios of $\frac{p}{p+w}$; the ultimate impact effect according to the formula will be the same.

It is significant to note that the formula $\frac{100 \times 180}{(L+20)U}$ has U in the denominator. This means that the increased load due to impact is $\frac{100 \times 180}{(L+20)U} \times \frac{U}{1} = \frac{100 \times 180}{(L+20)}$ B. S. Units and that such increased impact load is independent of U, the live load. The formula for impact due to track irregularities is written in the form $\frac{100 \times 180}{(L+20)U}$ with U in the denominator only for the purpose of office convenience. Therefore, the increased load due to impact on account of track irregularities being independent of the live load is a concept inherent in the formula $\frac{100 \times 180}{(L+20)U}$ and the author cannot use this formula for road bridges even indirectly unless he accepts the fundamental concept,

The author has found the impact percentage due to road irregularities by the expression

$$\frac{100\times 180}{(L+20)U}\times\frac{1+\frac{w}{p}}{1+\frac{w'}{p'}}$$ so that the increased load due to impact will be

$$\frac{100\times 180}{(L+20)U}\times\frac{1+\frac{w}{p}}{1+\frac{w'}{p'}}\times\frac{p'}{1}.$$ This is neither independent of p', nor of p, nor of U and as such the impact factors found by the author do not satisfy the fundamental concept involved in the formula $\frac{100\times 180}{(L+20)U}$ that the increased load due to impact should be independent of load and hence are not correct. Moreover, the author has made the impact factor due to surface irregularities in a road bridge to depend upon the number of B. S. Units adopted by him for the corresponding Railway Bridge. If the B. S. Units on the Railway Bridge are changed from 28 to 17, the author's impact coefficients on road bridges are also changed although there is no change in the conditions, of the road bridges or their live loads. Take for example a 30 feet span Railway Bridge with U at 17 B. S. Units. Then $I_1 = \frac{100\times 180}{50\times 17} = 21.18$ and the corresponding I_1 for the Reinforced Cement Concrete Bridge $= 21.18\times\frac{1+\frac{(0.4)}{3.09}}{1+\frac{1.06}{0.74}} = 9.9$ in place of 5.7 arrived at by the author.

Impact caused by the track irregularities is dependent to a great extent on the material of construction and it is not correct to find the impact percentage on Reinforced Cement Concrete Bridges by simply multiplying the impact percentage on steel bridges by the ratio $\frac{1+\frac{p}{w}}{1+\frac{p'}{w'}}$. The impact effects on Steel and Reinforced Cement Concrete Bridges may be different even with the same live loads and dead loads for the two bridges. The impact due to surface irregularities of a road and that due to rail joints and track irregularities of a railway are two different things different in character, action and effect and hence cannot at all be compared with each other.

The impact factors found for Reinforced Cement Concrete Bridges depend upon the data collected in Table 2 of the paper. Width of the T flange shown in the figure given under Table 2 does not satisfy the Indian Roads Congress Code requirements in case of a girder of 10 feet span Similarly a 6½ inches thick compression flange for a T beam 10 feet deep which is to have a resisting moment of 6450 foot tons is an impossibility unless compression reinforcement is used. Author has found the moment of inertia about the geometrical axis of the sections and has not taken any note of the presence of steel either in the compression or the tension side.

It should be noted that author's analysis is solely based upon some numerical figures giving the frequency, dead load, live load etc. in steel and Reinforced Cement Concrete Bridges. He does not take into account the character of the material and its influence on impact. Reinforced Cement Concrete is a composite structure and the working stresses at different positions and in different directions are more varying than in case of steel. Vibrations of a structural member involve movement on both sides of the position of static equilibrium and instances may not be wanting when due to such movements on the two sides, reversal of stress takes place *i.e.*, tension for compression and compression for tension. The consequences of such a state of stress in a Reinforced Cement Concrete structure will be very serious.

I wish in the end to emphasize one point. Impact factor in Reinforced Cement Concrete Bridges no doubt requires rational treatment. But the greater need of the time is to relate to actual conditions the Indian Roads Congress Loading itself. As it stands it is full of ambiguities.

I thank the author for his most interesting paper.

Reply of Mr. E. P. Nicolaides (Author) to Mr. Joshi's remarks.

Mr. Joshi has suggested the formation of a committee of theoretical and practical Engineers to investigate the subject of impact on Road Bridges by taking observations on Bridges. The Sub Committee for Impact on Bridges appointed by the Council of the Indian Roads Congress at their meeting at Lucknow in 1937, has estimated the cost of such an investigation to 4½ lakhs of rupees. The suggestion made by Mr. Joshi is certainly a good one and it is to be hoped that the Indian Roads Congress will be soon in a position to undertake an experimental research on Impact on Road Bridges.

On the technical remarks made by Mr. Joshi in connection with my paper I am replying seriatim hereunder:

2. In relating the possibility of resonance to the span of the bridge the general rule is that resonance is only likely to occur on large spans or more specifically on spans with low natural frequency. The pre-requisites for resonance are firstly a periodic force acting on the bridge and secondly a coincidence of the frequency of this periodic force with the natural frequency of the bridge. As the impressed periodic forces arising from the usual live loads carried by the bridges have always a low frequency, resonance is only likely to occur on the larger spans having a similar low frequency.

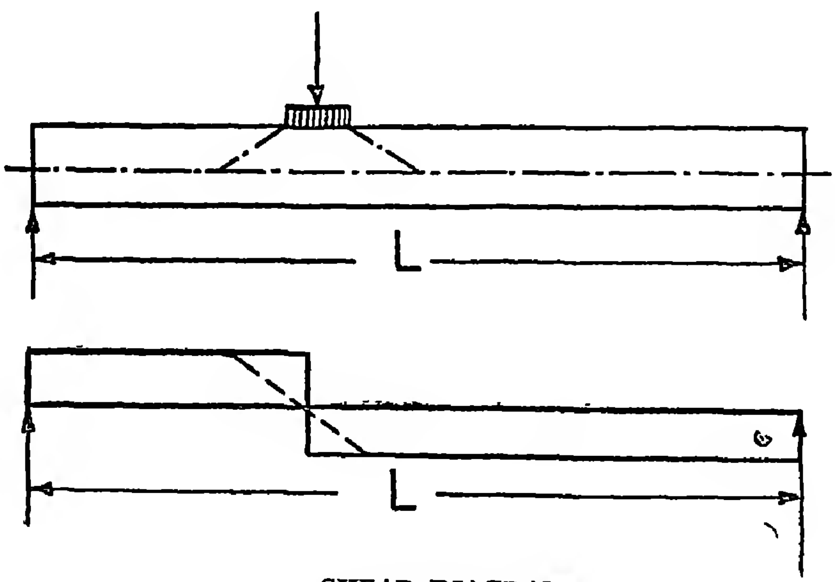
Mr. Joshi mentioned that certain theoretical investigations—probably those given in the paper by Messrs. R. W. Foxlee and E. H. Greet referred to in my paper—lead to the conclusion that Railway Bridge Girders of 100 to 120 feet span, having a frequency of about six, are subject to more severe impact effects. This is only true for the hammer blow impact of a definite type of locomotive producing a periodic impressed force having a frequency around six also. For other live loads on the same spans of 100 to 120 feet only moderate impact effects will be found.

While agreeing that a single impact formula having the span as the only variable cannot represent in a general manner all impact phenomena, I would point out that it is just as irrational to condemn this type of formula without offering a better alternative. A detailed calculation of

the various impact effects, taking into account all the available dynamical data particular to each combination of bridge and live load, is of course possible and certainly more rational, but owing to the inherent complications this alternative method of procedure is likely to draw little support from many practical engineers.

Under the circumstances the best compromise would be to have separate impact formulas for types of bridges with different dynamical characteristics and to adjust the coefficients in these impact formulas so as to cover as closely as possible the general results obtained for each case by more accurate dynamic calculations or tests. In my paper I have shown how this procedure can be applied to the two main classes of Steel and Reinforced Concrete Road Bridges.

3. The reversal of the shear force in the sections situated on either side of the point of application of a concentrated load acting on a beam is a fact inherent to the nature of the shear forces or more precisely to the method used in the Theory of Structures for the estimation of these shear forces. This reversal of shear forces occurs always irrespective of the load being applied suddenly or gradually; it cannot form therefore a criterion as to the action of the load being sudden or not. Incidentally it may be mentioned that the usual Theory of Structures does not give exact information on the intensity of the shear stresses in a section when a point load is applied at this section. All that can be determined is the shear stresses in the sections on either side of the point of application and these sections must be taken far enough from the point of application of the concentrated load to justify the assumption made that the normal stresses perpendicular to the axis of the beam are nil or small enough to become negligible. When the distribution of the concentrated load is taken into consideration together with the effect of the normal stresses perpendicular to the axis of the beam, the shear stress diagram will take the form shown in dotted line on the attached figure and it can be said that the sudden reversal of shear stresses mentioned by Mr. Joshi is merely a graphical simplification of an actually gradual variation of the shear stress.



SHEAR DIAGRAM

The main criterion for the sudden application of the load, or more generally for any dynamical phenomenon, is the increase in the deflection beyond the values given by statical methods; in the case of statical action it is known that however great the shear forces may be their effect on the deflection is negligible compared to the effect of the bending moments; the same rule applies also when the action is dynamical and the consideration of shear forces becomes unnecessary in this case also.

Free cantilever ends of bridges require more careful consideration but even there the action of the loads is far from sudden owing to the damping action of springs and rubber tyres, the indirect transmission through the road surface, deck slab, cross beams, etc. For these cantilever ends the impact allowance will be always a maximum owing to their short span. At the same time the necessity to limit the deflection at the ends of these cantilever ends, leads to sectional dimensions which are always much greater than the requirements derived from ordinary static calculations. In all cases this excess of strength will be found more than sufficient to take care of the more severe dynamical effects inherent to this type of girder.

What has been said above for the free cantilever ends does not apply to the cantilever ends supporting suspended spans in cantilever type bridges. There the reaction at the cantilever end increases gradually as the load approaches this point from the direction of the suspended span. The vibration affects the whole span between the supporting piers and the dead load of the whole span reacts to the dynamical action of the live loads; for this reason it appears reasonable in this case to take the span between centres of piers as the loaded length L referred to in the impact formulæ. When a roller bearing is provided at one end of the suspended span, owing to the lack of connection between cantilever and suspended span at this point, it may be safer to count the loaded length L between the centre line of the roller bearing and the centre line of the remote pier of the span.

The remarks mentioned above for the case of free cantilever ends equally apply to the end cross beams. It is usual in this case also to provide the end cross beams with greater sections than would be required by an ordinary statical calculation.

Mr. Joshi gives a formula for the dynamic deflection when the application of the load is wholly sudden. It is necessary to point out that this formula is not general and applies only to the deflection at the centre of a freely supported beam when a load P falls freely from a height h on the beam at its centre section. The speed v is related to the drop h by the usual formula $v = 2gh$. The formula as given by Mr. Joshi is also inexact,—the correct expression being:

$$f=f_{st}+\sqrt{f_{st}^2+\frac{f_{st}\times v^2}{g}\times\frac{1+\frac{w}{p}\,\frac{17}{35}}{\left(1+\frac{w}{p}\,\frac{5}{8}\right)^2}}$$

According to this formula even when $v = 0$ *i.e.*, when the load is applied on the beam without dropping on it, the dynamical deflection f is equal to twice the statical deflection; when there is a drop the dynamical deflection increases further beyond the double of the statical deflection.

But as I have already pointed out in para 6 of my paper these rather alarming results are not confirmed in practice; further they are also theoretically incorrect as the deduction of the above formula does not allow for the considerable amount of energy lost during the impact through the so-called momentary stresses, the local permanent deformations arising from the slight plasticity of the impacting bodies, the transformation of mechanical into heat energy, etc.

4. The reason for not combining in the same equation both inertia effects of the dead load of the beam and the live load, lies in the fact pointed out in para 4 of the paper *viz.*, that there is no accurate solution of the combined partial differential equation. It has been necessary, therefore, to give in para 3 of the paper the accurate solution possible only for the case when the inertia of the live load is ignored and to indicate in para 4 an approximate method accounting for the inertia effects of the live load.

5. When I received Mr. Joshi's comments on my paper I had already corrected the final proofs and I added there a note explaining more clearly what the factor $\frac{1}{1-c}$ represents in the impact formulas giving the effect of the centrifugal action. This factor provides for the effect of speed.

6. As I have already pointed out in my paper the impact formulæ for hammer blow given in the British Standard Specification No. 153 Parts 3, 4 and 5 (1937) are only a simplification of the more general formulæ worked out by Messrs. R. W. Foxlee and E. H. Greet in their paper on "Hammer-blow Impact on the Main Girders of Railway Bridges."

In order to find out the exact implications of these formulæ and to form an idea as to the probable values of locomotive hammer blow to be adopted in each case, it is essential to study the original paper. Without an accurate knowledge of the foundations of these formulæ the notes given in the British Standard Specification No. 153 Parts 3, 4 and 5 (1937) are likely to be interpreted wrongly and may become totally misleading.

The agreement established in my paper between the impact percentages calculated by the method I have suggested and the impact percentages derived from the experimental impact formula $I = \frac{65}{45 + L}$ appears, as Mr Joshi pointed out, to be incompatible with the contention of the British Standard Specification No. 153 parts 3, 4 and 5 (1937) according to which the impact percentages calculated by the impact formulæ given in this Specification for track irregularities, hammer blow and eventual lurching effect, agree also with the same Indian formula

$$I = \frac{65}{45 + L}$$

The fallacy lies in the fact that for the Indian Broad Gauge Railway Standard Loading (H. M. Standard 1926), the agreement in the impact percentages claimed by the British Standard Specification is non-existent. This can be easily seen from the following tables where the impact percentages for track irregularities and lurching obtained from the formulæ given by the British Standard Specification No. 153 have been tabulated together with the hammer blow impact percentages for the three cases of $P = 0.2$, 0.3 and 0.8 tons at 1 revolution per second.

Impact percentages according to the formulae given by the British Standard Specification No. 153, Parts 3, 4 and 5 (1937) and for the Indian Broad Gauge Railway loading H. M. Standard 1926 :

Span in ft.	10	20	30	50	70	100	150	250	400
Hammer blow Impact $P = 0.2$ tons at 1 revolution per second ..	19.6	14.7	11.5	11.3	17.7	18.5	14.3	9.8	6.7
Track irregularities	26.1	17.6	12.8	9.2	7.1	5.3	3.8	2.5	1.5
Lurching ..	18.2	16.7	15.4	13.4	11.8	10.0	8.0	5.4	4.0
Total ..	63.9	49.0	39.7	33.9	36.6	33.8	26.1	17.7	12.2
Hammer blow Impact $P = 0.3$ tons at 1 revolution per second ..	29.4	22.1	17.3	17.0	26.6	27.8	21.4	14.7	10.1
Track irregularities	26.1	17.6	12.8	9.2	7.1	5.3	3.8	2.5	1.5
Lurching ..	18.2	16.7	15.4	13.4	11.8	10.0	8.0	5.4	4.0
Total ..	73.7	56.4	45.5	39.6	45.5	43.1	33.2	22.6	15.6
Hammer blow Impact $P = 0.8$ tons at 1 revolution per second ..	78.4	58.9	46.1	45.3	70.9	74.1	57.1	39.2	26.9
Track irregularities	26.1	17.6	12.8	9.2	7.1	5.3	3.8	2.5	1.5
Lurching ..	18.2	16.7	15.4	13.4	11.8	10.0	8.0	5.4	4.0
Total ..	122.7	93.2	74.3	67.9	89.8	89.4	68.9	47.1	32.4
Impact from formula $I = \frac{65}{45+L}$	(118.3)	100	86.7	68.4	56.6	44.8	33.4	22.0	14.5

It will be noticed that for the spans above 100 feet the agreement is quite good for $P = 0.3$ tons at 1 revolution per second but in this case there is no agreement whatsoever for the spans below 100 feet. In the case of $P = 0.8$ tons at 1 revolution per second a certain agreement is reached

for the spans below 100 feet but for spans above 100 feet the impact percentages obtained by the formulæ of the British Standard Specification No. 153 parts 3, 4 and 5 of 1937 are more than 100 per cent higher than those given by the formula $I=\frac{65}{45+L}$.

The agreement claimed by the British Standard Specification arises from the comparison made by Mr. Foxlee between the results obtained by his proposed formulæ and the results of the Indian formula $I = \frac{65}{45+L}$, *vide* beginning of the Discussion on Hammer-Blow Impact and Moving Load Stresses in Railway Bridges pages 356 to 358, Vol. 237 of the Proceedings of the Institution of Civil Engineers, London. An examination of the curves drawn out by Mr. Foxlee will prove that the agreement is obtained only for spans greater than 100 feet for $P=0.765$ tons at 1 revolution per second, but without any provision for the effects of lurching or track irregularities; it is obvious that obtained in this manner the agreement claimed by Mr. Foxlee is purely fictitious. Impact formulæ drawn out from considerations of hammer blow effects only cannot normally cover also the effects of speed, centrifugal action, lurching and track irregularities all of which are included in the formula $I=\frac{65}{45+L}$ owing to its experimental basis.

Mr. Foxlee obtains the agreement of his hammer blow impact formulæ with the results of the Indian impact formula by raising the hammer blow value to the abnormal figure of 0.765 tons at 1 revolution per second. I doubt if such a high hammer blow can be found on any locomotive, but it is certainly absent from the modern Engines where the balancing of eccentric weights on the driving and coupled wheels is very nearly perfect. The value of 0.2 tons at 1 revolution per second has been recognized by all the Railway Engineers who took part in the discussion of the Paper of Messrs. Foxlee and Greet as the only figure acceptable for practical purposes. A confirmation that this figure adequately covers Indian Locomotives is given by Mr. Gelson in his Paper "Moving-Load Stresses in Short Span Railway Bridges" (Vol. 237, paper No. 4901 of Minutes of Proceedings of the Institution of Civil Engineers, London). Based on the experiments carried out by the North Western Railway the hammer blow value for the heavy XB class Engines (total weight of Locomotive 198.6 tons, maximum axle load 22 5 tons) is given by Mr. Gelson as 0.127 tons at 1 revolution per second.

Mr. Joshi has expressed the opinion that the hammer blow impact formulæ of the British Standard Specification cover also other effects besides the hammer blow. A reference to the paper of Messrs. Foxlee and Greet will prove that at no time have the authors examined any other effects besides the hammer blow. The British Standard Specification hammer blow formulæ are taken from Messrs. Foxlee and Greet's paper and in the words of the authors themselves the "statements" of their paper "are limited in their application to the hammer blow effects on main girders only". It is true that by raising the value of the hammer blow a certain agreement may be reached in the results obtained from these formulæ and the results of the Indian formula. But as I have pointed out the hammer blow value necessary for the purpose can hardly be expected in actual practice and the agreement presents no scientific interest.

In my tables I had to use 23 to 28 units British Standard Loading as this is the equivalent load to the H. M. Standard of 1926 adopted as live load for the Railway Bridge throughout the paper.

7. That the impact due to surface irregularities is proportional to the ratio of the live load to live plus dead load $\left(\frac{p}{p+w}\right)$ is derived from the classical theory on impact of two solid bodies as considered in Elementary Mechanics. Derived from the principles of this theory and familiar to all Engineers are the dynamic formulæ for estimating the carrying capacity of piles. In these formulæ the impacting force of the driving hammer is expressed in the general form

$$\frac{P^2}{P+W}K$$

where P is the weight of the hammer, W the weight of the pile and K a coefficient depending on the other characteristics of the driving process such as the drop of the hammer, the set of the pile, etc. It will be seen that in this formula also the impacting force is proportional to the ratio of $\frac{P}{P+W}$.

An experimental verification of the applicability of this same principle to bridge girders when the load is dropping on these girders from a certain height is given by the tests of Hodginson and Tredgold. These experimenters have attempted to find out whether the deflection of a steel beam is twice the static deflection δ_s when the load drops on the beam from a certain height instead of being applied gradually.

The results of the tests have revealed that the actual dynamic deflection is only $\frac{P}{P+W} 2\delta_s$ where again P is the dropping load and W the weight of the beam.

That the factor $\frac{p}{p+w}$ does not figure explicitly in the impact formula for track irregularities given by the British Standard Specification No. 153, parts 3, 4 and 5 (1937), does not contradict the above principle. For a steel railway bridge w is always very small compared to p so that the ratio $\frac{p}{p+w}$ is not much different from 1. In the case of the Steel Railway Bridge examined in my paper this ratio varies within the narrow limits of 0.95 to 0.83 in the range of spans between 10 and 100 feet.

For the Reinforced Concrete Road Bridge, however, owing to the much heavier dead load the values of the same ratio $\frac{p}{p+w}$ in the same range of spans from 10 to 100 feet vary from 0.72 to 0.09 respectively.

Mr. Joshi has expressed the opinion that the load inclusive of impact as given by the formula for track irregularities of the British Standard Specification No. 153 is independent of the live load itself and on the strength of this argument Mr. Joshi criticised the procedure used in my paper for deriving the impact percentages for Reinforced Concrete Road Bridges.

Mr. Joshi's interpretation of the implications of the impact formula for track irregularities is wrong; common sense and a careful reading of the Specification will prove that it is impossible to have the impact load independent of the load causing the impact,

The formula for track irregularities given by the British Standard Specification No. 153, parts 3, 4 and 5 (1937) is:

$$I_A = \frac{20\,Kn}{(L+20)U}$$

and it is clearly stated that in this formula K is a coefficient depending upon the type of floor and track construction, *the type of live loading*, etc. According to the same specification "the Engineer shall specify the appropriate value of K to be used" in each case but this value should not exceed 1.5. It is obvious that with a smaller value of U, a smaller value of K must be used. For the loading of U=20 ruling on the Railways of Great Britain the Specification gives K=1. As the Indian loading H.M. Standard of 1926 is approximately equivalent to 28 units British Standard Loading K may be taken equal to $\frac{28}{20} \sim 1.5$. If the same value of K is maintained for all loadings it would mean that on one and the same bridge a heavy train equivalent to 28 units of British Standard Loading would produce the same impact effects as a very light train equivalent to 1 unit only of British Standard Loading; this is obviously absurd. The method I have used in my paper for estimating the impact effects due to surface irregularities on Reinforced Concrete Road Bridges is, of course, approximate, but this method errs certainly on the safe side for the many reasons I have fully detailed in the paper.

8. In Table 2 of the paper, for a 10 feet span the width of flange used for the Reinforced Concrete beam section is $6 \times 6\frac{1}{2} + \frac{10 \times 12}{30} = 43$ inches while according to the Indian Roads Congress Code it should not exceed $\frac{10 \times 12}{3} = 40$ inches; the difference is not worth mentioning. For all the other spans the width of flange taken is well within the Code requirements. The calculation of the moment of inertia is in accordance with Clause D 20 of the Indian Roads Congress Code. It is usual designing practice to neglect the steel when calculating moments of inertia of Reinforced Cement Concrete sections for purposes of stiffness.

The moments of inertia used in Table 2, have been taken out from actual bridges designed and constructed by Messrs. J. C. Gammon Ltd. The rule given in Table 2 for estimating the moments of inertia as well as the formula $w=0.70+0.0004\,L^2$ for estimating the dead load of Reinforced Cement Concrete Road Bridges, given in para 2 of my paper, are actually derived from a comparison with the actual moments of inertia and dead loads of fully designed bridges.

9. I cannot help thinking that Mr. Joshi has neither read nor understood the paper properly, else he would not say that my analysis is solely based upon some numerical data. The numerical data are given only as an example of the application of the general theory and its fundamental principles enumerated in the first and second part of my paper. The usual Theory for the Design of Reinforced Concrete Structures and the corresponding factors of safety take fully into consideration the composite character of the material and the adequacy of this theory and its factor of safety has been tested on the innumerable Reinforced Concrete structures constructed since the discovery of Reinforced Concrete by Monier

nearly 100 years ago. Regarding the Resistance of Reinforced Concrete to vibrations, I would recommend Mr. Joshi to read the reports on the many tests carried out in the last 20 years on existing structures and in laboratories with a view to ascertain the behaviour of Reinforced Concrete under vibrating and alternating loads. The most important of these tests are those carried out by Professor R. Saliger in Vienna during 1930. These tests have established that Reinforced Concrete beams designed by the usual methods and subjected to a vibrating load behave in the same manner as under static action of the load. After submitting the beams several times to an oscillating load with more than a million oscillations at a time, with the stresses in the steel reaching 34000 pounds per square inch (about 60 per cent. of the elastic limit) and a compression in the concrete as high as 2100 pounds per square inch, the beams when tested have not shown any signs of fatigue either in the steel or in the concrete; there have been no appreciable alterations in the position of the neutral axis, the distribution of the stresses, the formation of cracks and the ultimate deflections before fracture, no damage to the bond and no reduction in the resistance as compared with the case of a static action of the load.

In fact in many instances the beams when subjected to the oscillating load have revealed smaller total and permanent deflections than in the case of static action of the load.

Similar results have been obtained recently in the tests carried out by Professor F. C. Lea and reported in "The Structural Engineer" of February 1940.

PAPER J—39.

Mr. K. G. Mitchell (President) :—The next paper to be introduced is "Roads in India and Australia—our difficulties and some suggestions" by Mr. W. L. Murrell, and Mr. Ormerod will be in the Chair.

Mr. H. E. Ormerod (Chairman) :—I request Mr. Murrell to introduce his extremely interesting paper.

The following paper was then taken as read :—

PAPER No. J—39

ROADS IN INDIA AND IN AUSTRALIA— OUR DIFFICULTIES AND SOME SUGGESTIONS

BY

W. L. MURRELL, B.C.E. (MELB.), A.M. INST. C.E.
Superintending Engineer, Bihar.

This comparative essay is written in Australia, towards the close of six months of leave, by an Australian who has served for about twenty years in India in the Public Works Department, chiefly on roads, but with considerable periods spent in building work and irrigation maintenance.

Furnished with letters of introduction from the President of the Indian Roads Congress, the writer was most courteously received by the Chairman and Members of the Country Roads Board Victoria, and the Commissioners of the Main Roads Department, New South Wales, and the Main Roads Commission, Queensland. These authorities placed me in direct contact with the very helpful heads of the different branches, and observations were made on about 4,000 miles of the roads of these three Australian States. Visits were also made to the laboratories and plant depots at the respective capital cities.

With a fairly vivid recollection of many Victorian roads and of some of the New South Wales roads of 20 to 25 years ago, I was simply amazed at the wonderful improvements since made, and at the great milage of new roads.

A quarter of a century ago, Queensland scarcely had any roads worthy of the name. It now has thousands of miles of road, and the work of road making and improvement is gathering impetus.

Though one sometimes hears Australians strenuously criticising their politicians and their many Government departments and local bodies, I heard nothing but praise for the roads boards, departments, or commissions, and for the road engineers of those bodies and the local Government bodies.

Let us face the plain facts in India today.

Though there has been some little improvement in the inter-urban roads during the last 20 years, the milage of new roads constructed is probably much less than one percent of the total road milage, and the all-important *katcha* road has scarcely been improved at all.

The comparison must electrify the average person in India who is responsible in an administrative or executive capacity for any portion of India's system of road communications.

Broadly speaking, even though India has no federation of states or provinces, the structure of government here is similar to that in the federated states or Commonwealth of Australia.

The Commonwealth Government of Australia corresponds to our Central Indian Government and levies customs and excise taxes on petrol, and import duty on motor vehicles and accessories. And it distributes a portian of this revenue on a population-area basis to the states.

The local governments of the Australian States are very similar to our provincial governments in India.

Until the roads renaissance started in Australia, the Public Works Department of each State was somewhat similar to the Public Works Department in each of the Indian provinces.

Until the roads renaissance commenced, the Australian local bodies, called shires and municipalities, were constituted much in the same way as are our district boards in India today.

And, as has been remarked already, until the Australian roads renaissance, there was in Australia much the same lack of progress, not to say stagnation, as we, or visitors, now see in India.

So it would be a very natural question to ask ' Why should we not adopt here in India the Australian methods of administration and technique ?"

Considertion of such a proposal immediately brings out the important differences between the Australian and the Indian conditions.

In Australia, the railways are all owned and controlled by the state or provincial governments, and the Central Government exercises no control whatever over the manner in which each state spends its allotment from petrol taxation.

As regards original work or work of improvement akin to original work, each Australian state decides to what extent it can afford to spend money on roads that will compete with its expensive and generally up-to-date railways.

In India we have Central Government control over all work to be executed from the proceeds of petrol taxation, and it would appear that, so long as the Indian provinces do not control the railways within their borders, this Central control must remain.

This being the case, in the belief that if a thing is worth doing it is worth doing properly, I would like to suggest that the Office of the Consulting Engineer to the Government of India (Roads) be expanded as rapidly as possible along the lines of the Bureau of Public Roads in the United States of America, with, in due course, Divisions of Control, Design, Information, Tests, Laws and Management.

In addition, there should be provincial control on the lines of the American or Australian state highway departments or commissions.

The American method of administration of roads is concisely described in the book "Highway Design and Construction"* by A. G. Bruce, Page 19.

* The book is available in the library of the Consulting Engineer to the Government of India (Roads).

The fairly typical Australian method of provincial road administration is briefly but well shown in an article by Messrs. McCormack and Fricke on page 361 of the Journal of the Institution of Engineers, Australia, Volume 6 No. 10, October 1934.

It may serve some useful purpose now to mention what appear to me to be a few of the more important of the difficulties that beset us in India, and to suggest some means of overcoming them.

Even greater than the difficulty of funds is the intolerable dictatorship of the steel tyre on the Indian bullock-cart.

This survivor of the Dark Ages in India it is that is chiefly responsible for the almost complete stagnation of the development of our road technique, and it is the steel tyre that, if allowed to persist, will throttle all development of agriculture, education, and whatever-goes to make a nation great.

I would invite a reference to the paper read by Mr. Moss and the discussion we had on it at the Third Congress at Lucknow in February 1937.

It is already late in the day for the road engineers in India to lead an irresistible revolt against the steel tyre of the Indian bullock-cart.

For many years, recognising the enormity of the task of abolishing the steel tyre, I, for one, have deluded myself in the belief that the segregation of slow and fast traffic would allow the continued use of the steel tyre, for then the bullock cart would not use the motor road.

It seemed that we could follow the American and Australian practice of building and maintaining roads which would cost but a small proportion of the present sums we now payfor construction and maintenance of water-bound macadam roads.

There would be a low cost road for the motor, and the popular demand of the carting fraternity would be met by furnishing a second low cost road, even if it were only a *katcha* one.

What I personally never realised, however, was the fact that it is absolutely impossible to construct any sort of low cost road that will stand up to steel-tyred traffic unless fabulous. sums are spent on maintaining it.

Here let me quote the "Statesman", overseas edition, for the 8th June 1939 :— "The bulk of the world's population is agricultural, and the key to the prosperity of the world is to make the country-man a consumer on a far larger scale of the goods and services which the towns can supply."

Let the reader substitute the word "India" for the word "world"! Let him mark well the words "goods and services"!

Services include hospitals with their X-ray, iron lungs, and other expensive apparatus for the specialised treatment of women, children and men, who live chiefly in the country. Services include special clinics of which the reader will know of at least half a dozen. More so than in most countries today, another name in India for Ignorance is Death.

Services include schools, taking pictures, future, television, shops, and personal contacts, which are all educating influences.

Services include the facility of buying in a competitive market, and services include much else besides.

Here is a remarkable corroboration of what the "Statesman" has said on national prosperity. Gippsland, in eastern Victoria, is essentially an agricultural area — dairying, sheep-grazing and cereals. Of it Messrs. McCormack and Fricke, in the article above referred to, write as follows :— "As an instance of the effectiveness of this work (road development), it might be pointed out that the valuations of the land in the Gippsland Shires in 1913 were £32.000,000 and in 1924 this had risen to £64,000,000. During this period practically the only development work undertaken in this large area was road construction."

So the greatest of all forces for education, prosperity, or uplift is the road, the low-cost road.

After the formation of a Central Bureau of Public Roads, including a Division of Transport, it would be possible to tackle the steel tyre problem on the only possible scale, *i.e.*, over the whole of India ; and all the provinces (and states also in the event of federation) could be prevailed upon to get all steel-tyred carts registered.

Registration would be followed, after a year, by taxation extending and increasing over a period of (say) five years, at the close of which the cost of the steel tyres would be prohibitive.

Simultaneously with the registration of carts, there could be started a system of subsidising the pneumatic tyre, as is done today by the Government of the North-West Frontier Province, but on a far larger scale.

And there is money that could and should be used to meet the exceedingly heavy cost of abolishing the steel tyre. I refer to the proceeds of taxation of petrol and duty on motor vehicles and accessories, to funds available from the taxation of the steel tyre, and to the funds which become available in the provinces for the work of less effective forms of social uplift.

But what would the automobile associations in India, and the Indian Roads and Transport Development Association think of a proposal to spend the revenue derived from their constituents on the purchase of pneumatic tyres for carts ?

The answer would be simple if these bodies sent their most formidable and conservative representatives to Australia to witness the speed and ease with which scores of thousands of cars and trucks traverse the earthen roads in the Australian countryside today There is now a network of low cost roads in each Australian state, each of which daily carries hundreds of tons on pneumatic tyres in all weathers. But put a dozen steel-tyred carts on any one of these roads and, in a few wet days, they would assuredly become impassable.

The answer must therefore be that the motor vehicle owner would agree that the first step is the abolition of the steel tyre, and also that, as time is the essence of the move, the motor vehicle owner must help to abolish the steel tyre.

In case it might be objected that the widespread adoption of the pneumatic tyre would be playing into the hands of private vested interests, it is suggested that, if local governments are capable of undertaking the supply of electricity and such national requirements on a large scale, they are easily capable of manufacturing and distributing at cost price pneumatic tyred for carts, the tyres being no less a national necessity than, say, water for irrigation. Besides this, it is doubtful whether private enterprise alone could meet what would be the demand for the tyres.

The very first step required appears to be the formation of a Central Bureau that will guide the provinces and arrange for their support in the new policy of steel-tyre registration and eventual abolition.

It may please be noted that, sticking to the engineering aspect only, no mention has been made of the humanitarian action of decreasing the strain on the draught animal by the adoption of the pneumatic tyre. Or, if loads are increased in view of the decreased tractive effort, less draught animals will be required. This should result in there being more grass for the cow, and the consequent better nourishment of the population. An improvement in the type of cattle might also result.

Again, next to deforestation, excessive grazing is the chief cause of the enormous national wastage by soil erosion. With bullocks reduced in number, first by the adoption of the pneumatic tyre and later by the substitution of the motor vehicle for the bullock-cart, it may be possible to approach India's great problems of soil erosion. At present we can do nothing.

Another difficulty that besets the road engineer in India is the lack of funds for construction and maintenance. These funds must be increased.

The time will come, and it may be sooner than we think, when India, among other countries, may need to spend less on national defence. It will then be reasonable to expect a considerably higher proportion of the petrol tax and customs duties on motor vehicles and accessories, to be allotted for road work.

To ensure that savings on national defence, or even other savings, will be given to the proper authorities for road work and not frittered away through executive officers in the civil departments on works of so-called social uplift, it will be necessary to have very strong representation through a Central Bureau of Public Roads, already organised to meet the occasion.

The taxation of the steel tyre has already been mentioned as a possible additional source of revenue.

The institution of tolls on large new bridges is a well-warranted procedure, provided that concessions are afforded to vehicle-owners residing in the locality of the toll bridge.

But the surest and the largest source of increased funds is to be obtained by increasing the number of motor vehicles on the road and the consequent demand for petrol, oil, and motor accessories

Obviously, the way to do this is to increase the milage of roads, and to make existing roads more attractive for motor vehicles.

As progress to this end must be slow, if only revenue be utilised, it is essential to utilise loan money.

This is how the Australian states started their roads renaissance, and the article by Messrs McCormack and Fricke tells the story, so far as Victoria is concerned.

The rapid increase in motor vehicles in the eastern states of Australia is clearly and even vividly shown in the annual reports of their boards, etc. to be found in the library of the Indian Roads Congress.

Many of our difficulties are due to the system of road administration existing in India.

Most of us, who have had anything to do with the preparation of projects to be financed from the Central Road Development Fund during the last 8 or 9 years, know that the one reason, why such heavy balances of the fund now remain, is that the programme of project preparation has been interfered with and upset by almost every change in the personnel of the annual committees known as the provincial roads boards

Personally, I have experience also of deliberate and unwarranted obstruction from local bodies, whilst engaged on project preparation.

I can also vouch for the fact that, owing to the great lack of experienced hands on the job and in the office, projects are not being prepared nearly so economically as they should be and, apart from this, practically no project is determined on a basis of traffic census.

It is, therefore, absolutely essential that each province should have a permanent or whole-time board or commission to fix the programme, work out the projects, and at least give guidance during the actual execution of work.

The Victorian Country Roads Board, typical of the permanent bodies set up originally in the eastern Australian states, consisted of two road engineers and one adviser on the Local Self-Government Act and on legal and financial matters

For several years after their inauguration, these permanent provincial boards, working each under its provincial minister, were very busy investigating, in conjunction with the local bodies, the requirements and resources of their provinces, and in developing their engineering and accounts establishment, accumulating plant, and taking over more road from the local bodies. There was no political interference except through the Minister of the day whose confidence the boards seem to have invariably possessed.

I have already referred to the very high and universal esteem in which the critical Australian taxpayer holds these provincial permanent roads boards or commissions.

Another point is that, whereas each Australian state decides for itself how much of its central fund will be spent on repairs and how much on original work, how much it will spend on establishment for new projects, on tools and plant, and on testing and research, etc., in India everything except original work must be financed from the meagre and fluctuating provincial revenue, so that inefficiency in methods and in maintenance will soon become even more evident than it is now. Indeed, I could quote the case of a project of considerable national importance which is held in abeyance because of the inability of the province to expend central funds on its future maintenance.

There are several other difficulties which arise because of our present system; but there is no time to mention more than one more, that of plant and machinery.

Apart from adopting low cost roads, we cannot even adopt modern methods for maintaining our present surfaced macadam roads. We use excessive amounts of tar and bitumen and obtain poor riding surfaces, which increase the stresses and consequently the maintenance charges on our roads.

Under the present system, no Public Works Department division nor district board could run to the not-so-very enormous cost of an oil-fired sprayer, road-mix drag, and lorry, or of a road-side mixer, drag-spreader, and a couple of lorries, togeter with the small trained staff.

Such would be charged to funds for the new supply of and repairs to tools and plant, which are already very meagre and barely sufficient for our relatively primitive methods.

But something might be done if the costs were charged to Public Works Department works and also debited against grants to local bodies.

It is in this respect that the provincial boards in Australia have such an enormous advantage. There they have much the same system as one sees in the army. Companies, battalions, and divisions carry the smaller and more usually required tools, whilst the special plant is carried by army headquarters and sent out to the divisions, etc. as it is required.

Thus an Australian provincial roads board sends out its road mixers drag-spreaders, compressors, breakers, sprayers, and the essentials for economical and reliable work, including skilled staff, to all parts of the state, and no public body is so small but it can get its fair share.

It is obvious that the Government of India can entrust the absolute disposal of large funds to provincial governments only if the latter have expert permanent roads boards. It certainly would not be good enough to leave such matters as the fixing of projects programmes, relative amount of repair fund, purchase of plant, etc. to the head, for the time being, of one of the departments working under the very busy minister for the time being.

Leaving the question of efficiency of system, let us now consider the matter of the personal efficiency of the roads engineer and his staff in India.

Personally, though I have had to spend some time in irrigation and purely buildings divisions, I have always been pretty keen on road work. Yet I must confess that, during my recent tour in the eastern Australian States, I could not but feel that I was scarcely more than a beginner, compared with the average road engineer with whom I came into contact.

But one would stoutly maintain that the relative inferiority of a roads engineer in India, as a rule, is not the fault of the man himself.

It is true that there are a few engineers in charge of roads who do not seem to recognise the need for improvement, as witness some glaring blanks in the list of members of the Indian Roads Congress but, for the most part, we are the victims of circumstances.

In practically every other country in the world the roads engineer sticks to road work, the buildings man to his buildings, the irrigation man to his irrigation and so on, each engineer reaching a reasonably high state of efficiency.

But here in India we engineers are Jacks of all trades and Masters in none, and so it is that in some provinces it is possible for one who has had little or no experience of roads to hold charge of a roads circle, or for one who has had little or no irrigation experience to head the irrigation department.

And our training, in most cases, has been so designed that it has fitted us to be jacks rather than masters This is because our rather impecunious technical schools and universities each have a lecturer or a professor who lectures on a subject known as "Civil Engineering", that is to say on docks and harbours, roads, sewage disposal, buildings, irrigation, and the many sub-branches of this branch of engineering.

It would be simply absurd to expect any one lecturer or professor to possess an intimate knowledge of a sub-branch, let alone keep himself a-breast of the times in it.

To put vividly, it is scarcely any wonder that the average academic mentor of the would-be road engineer scarcely knows the difference between tar and bitumen !

This state of affairs so impressed itself on a certain officer, when presiding over a board for the joint practical examination of students from three provinces, some time ago, that it appeared necessary to suggest that future students receive the benefit of hearing outside lecturers. In this the tar and bitumen interests in India have most helpfully co-operated, but a great deal still remains to be done in this way.

To make matters worse, circumstances are such that it is very difficult for us to gain knowledge subsequently Indian engineers sledom go abroad, owing largely to the expense entailed and, when they do go overseas, it is almost invariably to Europe where the European engineers also spend the leave. Europe can teach the road engineer from India very little about the road administration he requires, or about low-cost technique. He must go to those countries with large areas and high road milage per taxable head of population—to America, and especially to Australia, where all bitumen, petrol, and motor vehicles must be imported.

Then again, while on duty in India, we have but very little time in which to peruse journals and books on modern roadwork. Even the bulletins and pamphlets that are sometimes sent us gratis by the tar and bitumen interests in India must go un-read, or only partly appreciated.

This conclusion as to relative inferiority so impressed me during he tour in the eastern Australian States that I made a special point of mentioning our difficulties to the heads of the boards or commissions in the respective states.

These most friendly and helpful officials were very definite that there could be no question of lending technical staff for our instruction in India because, even though they recruit many men from the Australian technical schools and universities and put them through special training under their experienced engineers, the demand for skilled road engineers for the board and for the local bodies is still greater than the supply.

Then, still taking care to observe that I was merely a visitor presuming only on a demi-official letter of introduction, I asked whether it would be possible for any government in India to send graduates from Indian universities to receive training under skilled engineers, alongside the Australian recruits to the Australian highways boards.

The replies were of such a nature that there can be no hesitation in stating that, if the Government of, or governments in, India were to take up this matter officially, a most satisfactory arrangement would soon be made. As three or four years' training would be required, there is scarcely time to wait for the institution of a Central Indian Bureau of Public Roads to arrange for the training.

It is not suggested, of course, that India should continue to send batches of her younger engineers abroad indefinitely. The idea is that sufficient of them should go and become thoroughly experienced in all possible branches of the work so that, when he returns to India, each delegate will become a centre for the new technique which will be the first step towards a great roads renaissance in India.

The proposal to have a "roads technologist" has already been made in Bihar, and it is understood that it is receiving favourable consideration.

There are several other quite important points for comparison of the road work in India and in Australia, but one fears tiring the reader before the climax is reached.

The final suggestion now made is that the Indian Roads Congress pass a resolution suggesting that the Government of India consider the advisability of appointing a Commission to visit Australia and, if possible, America with a view to increasing the efficiency of road administration and the technique of road construction and maintenance in India.

At the risk of counting the chickens before they are hatched, or even before the eggs are laid, it is submitted that the proposed Commission should include the most experienced road-administrating engineer procurable any-

where in the world, an expert on Indian local self-government, an expert on central and provincial Indian finance, and an Indian roads engineer of wide knowledge of road and railway conditions in India.

The automobile associations of India and the Indian Roads and Transport Development Association should be asked to send their representative along with the Commission.

All should be good "mixers", for it would seem that, having read formal reports and papers, one gets the final and correct perspective of things only during informal chats, often at an impromptu luncheon.

If this paper be a scratchy and patchy painting of the conditions and possibilities in India as I most vividly see them, it is because the distractions, that are a part of one's leave, do not make the painting easy. On the other hand, whilst on duty in India, one has but little time for writing.

My excuse for writing is that, if any other member of the Indian Roads Congress had seen what I have been privileged to see, he would doubtless have done likewise. In modern times they do not serve who only stand and wait.

APPENDIX.

INDEX TO COLLECTIONS* IN AUSTRALIA, 1939.

SUBJECT.	FILE No.	CONTENTS.
THE PREPARATION OF ROAD PROJECTS.	1.	Instructions to Project Engineers Victoria and Queensland Sections, Culverts, Floodways, Surfacing, Alignment, etc. Typical specifications and plans for crushed rock road. Ditto New South Wales Safety arrangements, Conditions of contract and specifications. Chart for earthwork volume from end sections. Diagrams for waterways. Loadings and stresses. Standard cross sections. Typcal project plans. *Vide* also file No. 21 "Traffic Facilities and Amenities" of this collection and also file No. 2.
CURVE AND SUPER-ELEVATION, ALSO GRADIENTS.	2.	Cross Sections, Horizontal and Vertical curves, Tables for design of transitions, longitudinal grading, compound curves, Victoria, New South Wales and Queensland.
CAUSEWAYS AND CULVERTS.	3.	Flood or spill ways, pecifications and plans for pipe, precast and box, culverts, design instruction sheets for standard culverts, barrel and precast and single, double and multiple cell culverts.
SOIL TESTING AND STABILISATION.	4.	Australian report to International Roads Congress, shrinkage and minimum abrasion tests. Foundation and wearing surface design, classification of soils and gravels. Chart to ascertain metal thickness. Classification colour chart.
EARTHWORK AND WATER-BOUND ROAD SURFACE.	5.	The setting out of works, construction of formation, batters, drainage and consolidation. Construction of shoulders. Sand-clay surface and sections. Telford base. Water-bound gravel and fine crushed rock. Water-bound broken stone. Repairs to water-bound surfaces. Reconstruction with gravel.

* All the files referred to in this appendix are available in the Roads Congress Library.

SUBJECT.	FILE No.	CONTENTS.
PRIMERS AND BINDERS.	6.	Nature and purpose and rates of application. Preparation and use of tar. Contract supply and specification of tar for primer and binder. Preparation and use of bitumen. Tests Heating and spraying of binders. Contract supply and specification for bitumen. Ditto for tar oils for cleaning and cut-backs, Ditto for road oil and liquid bitumen and cut-backs. Contract supply and specification for emulsion and tar-bitumen compounds.
THE FLUXING AND CUTTING-BACK OF BITUMEN.	7.	Use of residual oil, tar, and tar oils in fluxing and cutting-back. Chart for proportioning above oils and kerosene for road mix seals and for surface treatment or painting or flush seals. Specification and supply of tar distillate and flux oil.
ROAD AGGREGATES.	8.	Nature and purpose. Grading. Average least dimension. Depth of aggregate to be 1.76 × average least dimension. Specification and supply of aggregates, sand, gravel, chips, broken stone.
SURFACE TREATMENT OF WATER-BOUND AND OTHER SURFACES PAINTING OR FLUSH SEALING.	9.	Preparation of surface Application of primer and binder. Application and rolling of aggregate. Signs to indicate work in progress. Broom drag surfacing. Tar as primer and binder, surfacing and re-surfacing. Bitumen as binder on primer tar, surfacing and re-surfacing. Likewise for fluxed bitumen. Surface treatment with bitumen emulsion. Detailed plans for drag brooms and drag.
DRAG SPREADING AND DRAG RE-SHEETING WITH PREMIX.	10.	Description and specification of work with hot mix and fluxed bitumen by mechanical drags, also with emulsion premix by hand drags with detailed plans of the drags. History of drag spreading. Reconstruction and resheeting by drag spreading. Smoothing courses on existing rough surfaces. Detailed plans and costs of mechanical and hand drags.
ROAD MIX SEAL	11.	Description of the work, plant and materials, also specification. Detailed plans and rough cost of the mixing drag.

SUBJECT.	FILE No.	CONTENTS.
BITUMINOUS ROADS FOR HEAVIER TRAFFIC.	12.	Asphaltic concrete, two-coat asphaltic concrete. Emulsion, straight bitumen, and tar penetrations. Modified macadam or partial penetration of stone macadam. Bituminous permixes.
CEMENT CONCRETE ROADS.	13.	Australian Report since the Internatianal Congress (Munich) on the use of cement for carriage ways, with particular reference to use of lean mixes 1: 2: 10, in rolled concrete. Rich mixes and jointing. Cement penetration with and without rolling. Specifications and type cross sections.
FENCING.	14.	Post, wire and netted fencing. Cable and chain mesh guard fencing. Ordnance fencing. With working drawings and specifications.
MISCELLANEOUS.	15.	Heat treatment of clay soils by oil-fired plant, standard sections dry rubble retaining walls. Hand railing, Name boards, varieties of tree guards with wooden and steel section posts. Anti white ant treatment. Arc welding Composite concrete and steel beams for bridges, with working drawings.
CONCRETE KERBS GUTTERS AND GULLEYS.	16.	Integral kerbs and gutters, cast iron gulleys, standard gulleys with specifications and working plans.
REINFORCED CONCRETE BRIDGES.	17.	Specifications deck and wearing surface, handrails, slabs for wings and abutments. Temporary timber approach platforms to cantilevered shore spans, General specifications. Composite joists and concrete slabs, Aggregates. Complete working drawings for two submersible bridges. Composite R.C slab and steel beam, and R.C. piers. One 60-70-60 feet and one 55-65-80-65-55 feet.
TIMBER BRIDGES AND CULVERTS.	18.	Specification for the supply of timber and for timber bridge construction, including piling, iron work and protection. Specification and supply creosote oil. Detailed plans handrail and beam, corbel and cap arrangements, with timber and steel beams, with standard sizes. Log culverts, dressed timber culverts span 12-18 feet and widths

SUBJECT.	FILE No.	CONTENTS.
		16-20 feet. Ordinary and low level timber bridges span upto 30 feet and widths 16-20 feet. All complete with sizes, details, plans and specifications. Complete working plans and specifications for high level timber truss 90 feet span, with 30 feet approach spans.
PLANT.	19A.	Plant operation, Extract from Victorian Handbook on surface treatment and copy of paper by J .D. Thorpe on heaters, sprayers and spreaders, road mixers and rollers Details road warning signs. Plans of test cylinders, boring gear assembly, caravans and pile drivers. Pictures of plant in operation. Manufacturers' catalogues. Detailed plans of lorry tailboard, scraper drags or planers, lorry trailer, disc and fantail spreaders, with approximate cost. Specification for supply of fuel oil. Returns for plant and fuel oil. Detail plan and approximate cost pneumatic wheeled roller.
PLANT.	19 B.	Detailed plans 400 gallons oil fired bitumen heater cost Rs. 3,800/-.
PLANT.	19 C.	Detailed plans 400 gallons oil fired bitumen and tar sprayer. Cost Rs. 10,500/-.
PLANT.	19 D.	Detailed plans rotary motor-drawn broom. Cost Rs. 3,600/-.
PLANT.	19 E.	Detailed plans rotary belt spreader or gritter.
PLANT.	19 F.	Detailed plans Victorian 400 gallons oil fired bitumen and tar sprayer. Cost Rs 10,500/- and of Queensland 400 gallons sprayer Rs 1,920/- and pre-heaters
COSTING OF LABOUR, MATERIALS AND PLANT.	20.	"Instructions to Overseers on Day Labour Works" as to the arrangements and costing for works in general and bituminous surface treatment in particular. Typical job records. Duties of permanent and work-charged staff. Sample forms of returns.

SUBJECT.	FILE No.	CONTENTS.
TRAFFIC FACILITIES AND AMENITIES.	21.	Provision for traffic during road work, Type guard posts. Specifications for supply of traffic zone-lining paint. Visibility discs and guard posts. Double tracking on sharp curves. Extract of Annual Report of Departmental Main Roads New South Wales for the year ending June, 1938 and from 25th Annual Report Country Roads Board Victoria with pictures of the amenities provided. *Vide* also file No. 1 "The preparation of Road Projects" in this collection and also file No. 2, "Curves, superelevation and gradients."

SAMPLES OF AUSTRALIAN TAR AND TAR-BITUMEN COMPOUNDS FOR PRIMERS AND BINDERS

Sample No. 1.—Primer tar. Crude horizontal retort tar. The many gas works in the state of Victoria with old fashioned horizontal retorts turn out good crude tar for priming. The Benalla tar is about the most viscous and the blackest of the series, and the best for the purpose. Unsuitable for mixing with bitumen, like all horizontal retort tars.

Sample No. 2.—Primer tar. This is from the Melbourne Metropolitan Tar Company with modern vertical retorts. Note the brown colour and less viscosity. This is not considered to be a good primer. The vertical gas retort tar could be mixed with bitumen in the same way as the New South Wales coke oven tar is, for priming, if the Victorian supplies of horizontal retort tar run short.

Sample No. 3. and 4.—These are priming tars made by the coke ovens of the steelworks of the Broken Hill Proprietary Company (B.H.P) Newcastle, New South Wales. Physical properties at 50° C. Engler 8 & 10 degrees respectivly, and poises 0·61 and 0·77 respectively.

Sample No. 5.—Priming tar. A mixture of the B.H P. coke oven tars above referred to, with straight bitumen. Largely used in New South Wales and Queensland.

Sample No. 6.—Binder or sealing tar. Distilled from B.H.P· coke oven and called No. 2 Road Tar. Float test 5-50°=-80 seconds poises at 50°C.

Sample No. 7.—Binder tar bitumen compound. A mixture of B.H.P. No. 2 coke oven tar with straight bitumen. Penetration at 25°C= 110, or 8500 poises at 50°C. This is used in lieu of straight bitumen in surface treatment etc. in New South Wales and Queensland.

Note.—For detailed specification, tests and contracts for supply *vide* "Primers and Binder" File No. 6 of "Collections in Australia 1939".

Enclosed with the tar samples is also a tin which is typical of tins used by the Department of Main Roads New South Wales for sending specimens. It is of special and very effective design.

DISCUSSIONS ON PAPER J—39.

Mr. W. L. Murrell (Bihar) :—I have great pleasure in introducing my paper "Roads in India and in Australia."

I would like to invite your attention to the 'Index to Collections in Australia 1939' printed as an appendix (page 11 j) to the paper which has been circulated to you.

On the tour in Australia, I collected such matter as appeared would be useful to road Engineers in India, and classified it as shown in the Index. The lot has since been accepted for our library.

I would very strongly recommend to anyone who is disposed to experiment on any road work, or who contemplates framing a specification or writing a paper, that he first obtain the relative Australian file from the Secretary to our Congress. A few of these files Nos. 7, 9, 10, 17, and 21 are of very considerable importance, as I hope to show when certain papers are discussed before this meeting of the Congress.

As regards the samples of tar and tar-bitumen compounds referred to on page 16 (j), these also were sent to the Secretary of the Congress, who has brought them here. My reason for fetching such samples was to stimulate the idea of combining imported bitumen with the indigenous tar in order to decrease binder costs, at least in eastern India.

Concerning the steel tyre, it appears to me almost as some all-destroying monster waiting in the centre of a large field for us to go out and challenge it.

That field is the ground on which, if we are to be good servants of India, we must fight the battle for the low-cost road.

The great majority of us hang about the edges of the field shouting unconvincing defiance at this monster, in terms of tar, bitumen, and cement.

A brave few, like Messrs. Mehra and Breadon, propose to go forth into the field to do battle with the monster, using only the weapon of soil stabilization. They are doomed to defeat. Soil cannot be stabilized against the steel tyre.

It appears to me, therefore, that there is nothing for it but for us to appeal for the help of the Central Government.

I shall presently read to the Congress a draft resolution asking that the Government of India should appoint a Committee to enquire into the delay in road development, and the share of the steel tyre, amongst other things, in causing such delay. It is hoped that this meeting will consider the advisability of resolving accordingly.

I would be glad if anyone speaking on my paper would realise that it is the steel tyre and NOT THE BULLOCK CART which is the object of attack.

Also I would be glad if each speaker would state whether he would or would not support a resolution similar to that proposed.

(The following draft resolution was then read by the author).

This congress, constituted by the leading highway engineers of the Governments and local bodies throughout India, and by the representatives of all the important highway construction and transportation interests,

(*a*) emphasises that, although roads are a Provincial subject, the similarity of the problems which they present throughout India makes them a matter of National importance. This fact appears to have been realised over ten years ago by the formation of the Road Development Committee, and by the creation of the Central Road Fund.

(*b*) Emphasises the supreme importance to the *ryot* and to agriculture generally of an adequate system of rural roads.

(*c*) Believes most strongly that one of the greatest obstructions to progress in obtaining a system of rural roads is the steel tyre of the bullock cart, unrestricted in design and loading and in the roads over which it may operate.

(*d*) Considers that the progress made in the provision of roads and bridges since the Report of the Road Development Committee has been wholly inadequate, owing chiefly to difficulties not foreseen and which could not be foreseen by that Committee.

(*e*) Considers that the time is ripe for a complete review of the whole position, and that such review is a matter of National urgency.

And, to this end this Congress recommends to the Government of India that, in order to prepare for an adequate and progressive road policy after the war, a Committee be appointed forthwith.

(1) To examine the present position as regards roads in India, the extent of their inadequacy to the reasonable requirements of a modern nation, and in particular to the amelioration of the conditions of and to the social uplift of the rural population.

(2) To examine the progress made in other countries, and the administrative and financial means by which such progress has been achieved, particularly in the self-governing Dominions.

(3) To examine how far the steel tyre is an obstacle to progress and in what way that obstacle can best be overcome.

(4) To consider the present practices of road construction and maintenance in India with special regard to the best use being made of indigenous and local materials, and for the Committee to make recommendations.

The draft resolution is a pretty long thing, but it has got to be so. This resolution was not included in the paper, but it seems to me that now is the time to introduce it.

Mr. H. E. Ormerod (Chairman) :—In asking you for an expression of your views on the extremely interesting paper, I would like to suggest you to provide us with constructive proposals as to how best to give effect to the more important proposals contained in the paper. You will all agree, I think, that the paper gives us considerable food for thought, and I hope the suggestions made will be given the consideration they deserve.

Mr. S. B. Joshi (Bombay) :—It is a matter of regret that this Paper should be in striking contrast to the most balanced speech delivered by our President, at the opening of this Session. The Chairman thinks this to be an interesting paper and invites constructive suggestions. My only suggestion is that this Paper should not at all be considered by this body (Laughter). I am very serious in what I am saying.

It is gratifying to note that the author has spoken out the whole truth by not restricting his criticism to steel tyres only. He does not spare the bulls and the bullock-carts. Although he has outwardly shown great sympathies for the bulls and the bullock-carts, and pleads humanitarian motives in prescribing pneumatic tyres for the bullock-carts—he has not been able to conceal his desire to do away with the bulls altogether. He opposes segregation of bullock-cart traffic from motor traffic on the ground that such a measure will not help in driving away the bull from the road which appears to be his goal. It is interesting to read what the author has said on page 5 (j), para 5, of his paper.

"Again, next to deforestation, excessive grazing is the chief cause of the enormous national wastage by soil erosion. With bullocks reduced in number first by the adoption of the pneumatic tyre and later by the substitution of the motor vehicle for the bullock-cart, it may be possible to approach India's great problems of soil erosion. At present we can do nothing."

The author foresees a reduction in the number of bullocks first by the adoption of pneumatic tyres and later by the substitution of the motor vehicles for the bullock-cart. So, the purpose behind the introduction of pneumatic tyres is to reduce the number of bullocks! Whether the bulls are on the roads or in the fields—they are bound to graze. The fact of the matter appears to be that the author wants to finish with the bullocks and desires the introduction of motor vehicles and other machines in the village life of India. He suggests registration of bullocks and bullock-carts, and proposes to tax them. This is really unfair.

Our present day road problems are created not by the steel tyred bullock-cart. A slow moving bullock-cart does not need either the concrete road or the asphalt road. Ordinary macadam road is all that it wants.

It is the modern fast moving traffic that has created a serious problem for the road engineers. Let this fast moving traffic take the burden of taxation required for constructing roads to suit it. It is unfair to transfer the burden on the shoulders of the bullock-cart. Damage done to the road is not caused by the bullock-cart. It is due to the combination of the slow moving and fast moving traffic on the same road.

Some might ask me why I am taking the side of the bulls. The bull is a great factor in the village economy of India. Yesterday our President said that the advent of the roads and railways had improved the lot of our villagers. My experience is that it is not so, and if theory does not tally with practice, the theory must be wrong. You will concede that I know the condition of our villagers better than many of my European friends here.

Elimination of the bullock and bullock-cart will seriously affect the village economy of India. I am not opposed to the introduction of

machinery as such, but the introduction should be so gradual as not to throw out of employment thousands of villagers. It is a generally accepted proposition that rapid introduction of civilization in a backward country kills that country. This is an economic truth. The introduction of machinery deprives thousands of villagers of their daily-work, and the introduction is so rapid that there is absolutely no time for readjustment by way of giving *substitute employment* to those whose daily bread the machine has snatched. The result is starvation and death. With such a catastrophe, you will have good roads but no villagers to use these roads.

It is no use comparing India with Australia as the author has done. The population of Australia is so small that there are hardly 2 men per square mile. In India there are more than 180 men per square mile. In Australia there is a difficulty of finding men to do all the work. In India there is difficulty of finding work for her vast population.

On page 3 (j), the author has given the following quotation from the 'Statesman'. 'The bulk of the world's population is agricultural, and the key to the prosperity of the world is to make the countryman a consumer on a far larger scale of the goods and services which the towns can supply.'

The author wants us to substitute the word India for the word 'world'. An extremist expressed to me his doubts whether there was any intention to carry Lancashire goods to the villages for the prosperity of the Empire You can see how suspiciously some of them are looking unto you. It is really necessary that European Engineers should be very careful to see that their unconscious writings do not arouse such unwarranted suspicions.

I entirely agree with the author that our students should go abroad to see what is being done in other countries. But instead of doing that, our students go abroad to obtain academic degrees of questionable value but which are given undue preference in making appointments to good posts. I wish the money were usefully spent in travelling in Australia, Canada and other countries.

I know I have been very strong in my criticism. I have deliberately done so. There are very few amongst us here who would put this point of view before you I have conveyed to you the views of a vast number of people outside this body. If these views are to be impressed upon you by the efforts of one man, they must be expressed with great emphasis. That is what I have done.

Nawab Ahsan Yar Jung Bahadur (Hyderabad-Deccan) :—Without being rude to anybody, I must say that Mr. Joshi has lost sight of the technical aspect of the problem, and perhaps he has done so in his zeal for nationalism.

I think the steel tyre is at the root of all our road troubles. It is a technical matter and every engineer will admit it. Mr. Joshi knows the subject well; but I do not understand why he wants to get away from the fact that steel tyre is causing the trouble. We are not against bullocks, or bullock-carts. But there is no denying that the whole trouble is due to steel tyres of the carts. We must, therefore, put our heads together, and see whether we can improve this tyre, and also keep the bullock-cart in existence instead of exterminating it. The best way of

solving this problem is to try and find out some means of either manufacturing the pneumatic tyre very cheaply or of making such financial arrangements that the ordinary villager or cartman can afford to purchase it. It is no doubt true that the motor car when driven with a great speed destroys a murum road quicker than the steel tyre, but the steel tyre cuts the surface just as well. In conclusion I say again that we must put our heads together and devise some means of improving the tyre.

Rai Sahib Lala Fateh Chand (Bijnor) :—I must express my gratitude to the author for having introduced such a useful paper. I do not agree with Mr. Joshi that the paper was unnecessary. I think that if we can proceed on the lines suggested by the author we can remove the stagnation, and accelerate the progress of road communications in our country. I may say that it is for want of a Central Board of Communications and the existence of Provincial Boards of Communications, as also due to unequal distribution of the proceeds from the taxes realised on petrol or on motor vehicles that there has been so much stagnation in our work. In the United Provinces, before 1938 we did not use to get anything out of motor taxes, though all the roads were allowed to be used by such traffic. If there had been a Central Board I think the march of our progress in road construction would have been very much quicker. I therefore entirely agree with the author that there should be a Central Body like the ones in America and other countries with the Consulting Engineer to the Government of India (Roads) as its President and with some engineers as its members. That body should lay down a policy and control the activities of the Provincial Boards which should chalk out programmes. It is difficult to check the obstructive tendency of local bodies in such matters, but if the Central Government collects taxes on petrol and distributes them amongst the various bodies, it can effectively control the policy through a grant-in-aid. I think this is the best way of solving the problem. I think the author has done us a great service by referring to the huge waste that is going on at present for want of proper and technical supervision over the works now carried out. It will be something if the Provincial Boards exercise some supervision and control over the money spent by the local bodies given to them by way of grants.

The other constructive suggestion made by the author is to send a commission to America or Australia to collect information about roads, and then present such information to the members of this Congress in the form of a paper. It is a very good suggestion. Another suggestion which I make is that it should be made obligatory on every road engineer to attend the Congress at least once in 5 years.

As regards steel tyres, I would say this. In our Province they were a menace to the roads which have greatly improved since some of us have made it a condition that the contractors should bring the necessary materials only in motor lorries. My friend Mr. Joshi said that if machinery comes in, labourer will die. I say that there should be no labourers and coolies in our country, and for that we must raise their status.

Mr. Nurmahomed M. Chinoy (Bombay) :—I speak with a certain amount of diffidence in this gathering of technical experts; but to one who has watched the proceedings of this Congress, and has seen some of the best brains in the road-building profession devote themselves year after year to the task of facilitating and promoting the technique of the development

of roads, it cannot help occurring that very little of the valuable contribution thus made to this branch of knowledge seems to take root in the soil for which it was meant.

These reflections are prompted by the instructive and thought-provoking paper presented to us by Mr. W. L. Murrell, on Roads in India and Australia. The comparison of roads in these two countries furnishes a pretty commentary on the methods of administration pertaining to roads followed in India.

The author of the paper asks: "Why should we not adopt here in India the Australian methods of administration and technique ?" Why, indeed, should we not ? The only reason that I can see is that the will is lacking. It is not lack of means or technical knowledge that we have to overcome, but mental inertia, which is an obstacle far more difficult to surmount.

This is not the first time, for instance, that attention has been drawn to the heart-breaking burden that the steel-tyred carts constitute on our road finances In particular, the conclusion reached by the author that the extensive network of roads in Australia, each carrying daily hundreds of tons of traffic, would assuredly become impassable if a dozen steel-tyred carts were put on them for a few wet days, should give one furiously to think.

May I, therefore, make an earnest appeal to Provincial Governments to lose no time in taking measures to combat this scourge that is eating into the vitals of our communications system, and holding up the progress of our country ? Isolated and patch-work measures will not be of any avail. What is required is a country-wide Government-subsidised campaign to abolish the steel-tyred carts. Admittedly, the conversion of such carts to pneumatic-tyred wheels will take time and cost money—and lots of it. But let it be remembered that any expenditure so incurred will be more than fully repaid by the substantial savings in our road maintenance bills in the years to come. In view of this, we would not even grudge if a part of the funds normally spent on road projects were set apart for the conversion of steel-tyred carts into pneumatic-tyred ones.

There are other constructive suggestions which the author puts forward, such as expansion of the office of the Consulting Engineer to the Government of India (Roads), and the appointment of permanent and full-time Commissions in the Provinces to prepare more balanced, and economically better planned, programmes of road projects. May one dare hope that these suggestions will receive the serious consideration of the authorities ?

Mr. Dildar Hosain (Hyderabad-Deccan) :—In the short space of time which is allotted for the discussion of the paper it is not possible to make more than a passing reference to the valuable contribution made by Mr. Murrell to the questions before the Indian Roads Congress. The issues that he has raised are such on which volumes could be written and spoken. While some of us might not agree with him on several points, there can be no two opinions that the expansion of the road system on an organized plan is necessary and that it is long overdue. It is generally recognized that the existing road system in India is not the result of a predetermined or planned effort. According to the report written by our worthy President in collaboration with Mr. Kirkness on the question

of road and rail competition, half the railway lines are duplicated by roads situated within a distance of 10 miles. The result has been that both the road and rail transport have developed along the main trade routes much to the detriment of other routes.

The motor transport, while it added to the revenue, also increased the expenditure on the upkeep and improvement of road surfaces. Let us, therefore, see how far the development of motor transport has helped or affected the Finances of our country. Now according to the report for the International Chamber of Commerce written by Dr. Wehl and Prof. Albitreccia (Oxford University Press) the total taxes paid by Indian motor transport in 1931-32 amounted to Rs. 830 lacs. This amount was allocated to the following credit heads :—

100 lacs Central Road Development Account.

430 lacs Central Revenue Account.

300 lacs Provincial, State and Local, (P. S. Revenue).

It is interesting to see that out of the total contribution of 830 lacs, not less than 600 lacs were contributed by the eight Governors' Provinces. But what did they get in return ? The average expenditure incurred on new construction in these provinces amounted to Rs. 167 lacs only plus about 90 lacs on increased maintenance. In all about 257 lacs were spent on roads against Rs. 830 lacs yielded by the motor transport. The figures given by our President in his address also point in the same direction.

The conclusion that one can draw is, therefore, that if more of the amount realized from motor transport had been spent on road construction and modernisation of surface, our system of road communications might have made some marked advance. It does not require any logic to convince that the first demand on the amount yielded by the motor transport, rightly and legitimately, is that of road construction and improvement.

It might perhaps interest you to know that in Hyderabad (Deccan) the whole of the amount realized from motor vehicle tax, apart from the normal annual budget grant, is spent for the roads. The principle that has been kept in view is that in all district towns and important commercial centres the roads are to be gradually made dust-proof. This is invariably done with cement concrete.

Therefore, as I have stated above, if more of the money derived from motor transport had been spent on the construction of new roads in India, depending, of course, on the requirements of each region, it would have helped the growth of a road system that would have indirectly added to the economic development, increased use of the motor vehicle and given more revenue.

To launch an offensive against the bullock cart in the manner suggested by the author is, therefore, not only premature but one requiring serious consideration as the economic conditions of the cultivator have also to be studied. As some one put it humorously, the bullock cart is the only circulating capital of the farmer in India.

With the expansion of the road system in Australia, the revenue from motor transport also increased. For instance in 1926 it amounted to £ 2,235,751. But unfortunately it seems to have had an adverse effect on the Australian Railways. Between 1915-32, the Australian Railways suffered a total deficit of £ 68,467,158, the rate of deficit varying from 5 million pounds to 10 million pounds annually.

It would have been interesting if the author had given us an idea of the nature of road surfaces in Australia. According to the available statistics the roads are described as main roads, development roads and other roads, the bulk of the road milage being of the latter class.

It would be useful to know how the system of road construction in Australia was financed and how the financial liabilities met with.

The author suggested that, with a view to eliminate the disastrous effects of the steel tyre on our roads, a system of registration followed by taxation should be adopted so as to lead to a gradual substitution of the motor vehicle in place of the bullock-cart. No doubt in Australia there is one motor vehicle for every 10 of population whereas in India there is one vehicle for every 1883 of population, but it would be helpful to know whether the problem of exchange, currency and tariff are also the same in Australia as in India ?

Mr. T. Campbell Gray (Madras):—In considering ways and means of overcoming the excessive damage done to roads by steel-tyred bullock-carts, it has always seemed to me that in recommending the immediate substitution of pneumatic tyres with elaborate steel shafts in ball bearings we are advancing in too rapid a stride. I would, therefore, ask the author if, in his view, it might not be better to aim at a gradual transition from the steel-tyred wheel to the pneumatic tyred one by first of all encouraging the use of solid rubber tyres which might be fitted to the ordinary cart wheel either by the inclusion of a suitable groove made when turning the wheel out to its finished diameter or by cleats screwed on.

I do not know if this suggestion has been made previously or if any investigation as to relative tractive effort of solid and pneumatic tyred bullock-carts has been made but we are all aware of the large number of heavy, though comparatively fast moving motor lorries equipped with solid tyres and the cushioning effect obtained must represent an advance on steel tyred equipment as regards undue wear on the roads.

The cost of pneumatic tyred equipment for bullock-carts is far beyond the means of the average cart owner as is also the cost of renewal of tyres and tubes, there is also the possibility of carts so equipped, in the event of puncture, running on a flat tyre. Would it not, therefore, in the opinion of the author, be advisable to explore the possible advantages of the cheaper equipment before advocating the formation of the Central Bureau mentioned on page 5 (j), para 3, of his paper for guidance of the Provinces on the new policy of steel-tyre registration and eventual abolition.

Mr. A. Lakshminarayana Rao (Madras):—I feel sure that I echo your sentiments when I state that we should be all very grateful to the author for having spent his leave in studying roads of Australia with the view of helping in the solution of some of our problems in India. The paper is full of helpful suggestions and the sentiments expressed in paras 5

and 6, page 8 (j), show a courage of conviction to which I can pay the homage of repeating them:

"In practically every other country in the world the roads engineer sticks to road work, the buildings man to his buildings, the irrigation man to his irrigation and so on; each engineer reaching a reasonably high state of efficiency. But here in India we engineers are Jacks-of-all-trades and Masters-in-none, and so it is that in some provinces it is possible for one who has had little or no experience of roads to hold charge of a roads circle, or for one who has had little or no irrigation experience to head the irrigation department." I heartily endorse these sentiments and appeal to the Indian Roads Congress to pass a resolution requesting provincial administrations to stop this anomaly as far as possible. In Madras, the roads are mostly in direct charge of road engineers alone, though the inspecting agency is not immune from the above anomaly and this is perhaps the reason for Madras being ahead of other provinces in the matter of being equipped with hard surfaced roads as remarked by our President in his presidential address yesterday morning. It may not be possible in smaller units of administration to correct the above anomaly but it must be possible to correct it in the case of Provinces and I request you all to pass the resolution as put before the body.

I must, however, differ from the author in his diatribe on the Indian bullock cart and its steel tyres in paras 3 and 4, page 3 (j). I am sure, however, that the author had not meant all he said in the above paras. In India there are 20 lacs of villages roughly, and one crore of carts. In the United Provinces alone, there are 11 lacs of carts (*vide* His Excellency's speech at the opening of the Indian Roads Congress 1937), and it will take Rs. 100 to equip each cart with a set of pneumatic tyres. Hence the total cost will be Rs. 100 crores, a figure that would stagger the imagination of any practical engineer. Next, of these one crore of carts, 90 per cent belong to the agriculturist and are used for carrying his manure to his fields and his produce from the fields and an occasional trip to the nearest market town. It matters little from the practical point of view what tyres this agriculturist uses. Even if some philanthropic road enthusiast or a finance member of Mahomed-Bin-Taglukian fame presents them tyres free, the cost of their maintenance will be at least Rs. 20 per annum on repairs and replacements as the tyres perish in 5 years whether they are used or not, against Rs. 2 which he actually pays now by way of a few petty repairs to his cart executed by the village blacksmith. The plight of this agriculturist is so miserable that the extra repairs would ruin him. I am in direct touch with these *ryots* and know how miserably fed and clothed they are and what a collosal difference Rs. 18 makes in their budgets. The presentation of these pneumatic tyres will be a present comparable to that of white elephants supposed to have been made by the Emperor of Siam when he was displeased with his nobles.

But there is the remaining 10 per cent. (10 lacs of carts) which ply always for hire, make a decent living on hire and destroy our roads by frequent trips in fair and foul weather. I presume it is these that the author has in his view. It is, therefore, desirable that only those carts which are plying for hire should be registered and induced to purchase pneumatic tyres, by the aid of interest-free loans granted by Government. The problem will then become practicable of solution.

May I also remind the author that $1\frac{1}{2}$-inch plano-convex steel tyre is not the survivor of dark ages but a product of the 20th century steel manufacturer of the west and that the wheel of ancient India had only broad wooden wheels that weared not the road but weared themselves, and may I appeal to him to modify these paras so as not to tread on the corns of the Indian economist, lest it be said that the Indian Roads Congress is unsympathetic towards the miserable Indian agriculturist who is bearing the burden in society like the ass of the Irishman and wants him to suffer for the benefit of rubber tyre magnate. As I am sure that the author's intentions are not unsympathetic towards the agriculturist, I feel hopeful that he will modify the language of the above para in the proceedings that are to appear finally.

With reference to Mr. Joshi's remarks on the paper, I may say that we know perfectly well that our well-being is largely dependent upon the agriculturists. They are our arbiters. We never mean to destroy them or to harm them. It is on the other hand our idea to protect them, to foster their interests and to construct roads for them so that they may take their produce in any part of the year to the nearest market place and get the maximum price for it.

A suggestion has been made by Mr. Campbell Gray that we should first start with solid rubber tyres and then go to pneumatic tyres. I had a discussion on this topic with the Transport Officer of the Travancore State. It was ascertained that a pair of solid tyres to be fitted to the bullock carts will cost no less than pneumatic tyres. Moreover, solid tyres will not help much in traction. So, by adopting solid rubber tyres no appreciable economy will be derived, nor will it solve the road difficulties.

With regard to the resolution proposed by the author, I propose that in line 4 of clause (c) of the resolution, the words "plying for hire" should be added.

The author had in his "scratchy patchy painting" attempted to portray a very wide panorama and as it would take a considerable time to commend or comment on the details of the picture, I desist from the attempt, however tempting it is, and close my remarks.

Mr. D. E. Gough (Bombay):—I am sure we are all very much indebted to Mr. Murrell for his extremely interesting paper. Personally I do not remember having read a paper which has impressed me so much, and I feel sure that most of us at any rate will hope that the Government of India will give very careful consideration to Mr. Murrell's paper. I have no criticisms to offer, and so I do not intend to say much.

In the last para but one on page 4 (j) Mr. Murrell asks whether the Indian Roads and Transport Development Association would favour the spending of funds from the Petrol Tax and Motor Vehicle Import Duties on the purchase of pneumatic tyres for carts.

Now, unfortunately, I have not been able to obtain the opinion of the Council of the Indian Roads and Transport Development Association upon this particular question, but, in my own mind, I have little doubt of what it will be. The Association has always advocated that these funds (being obtained from Motor Transport) should rightly be spent upon roads. The purchase of pneumatic tyres for bullock carts is surely only another

way of spending money on roads. There is no need for us to touch the $2\frac{1}{2}$ anna of the petrol duty which now goes to the Road Fund.

If we could only have the remaining $7\frac{1}{2}$ annas of the petrol tax and the motor vehicle import duties, we should receive about $6\frac{1}{2}$ crores of rupees a year.

There are said to be 8 million bullock-carts in India, but I suggest that not more than a half of these use made up roads. Four million bullock carts would cost about Rs. 60 crores to convert.

This could easily be done by loans raised on the strength of the $6\frac{1}{2}$ crores per annum income and there would be lots to spare. The economic benefits resulting would be immense.

It really is nothing short of insanity to spend large sums of money in making good roads and then allow carts to smash them up. It seems to me that it is far sounder to spend part of the money on good roads and part of the money on good bullock-carts than to spend more on good roads merely to have them ruined by bad bullock carts.

The whole problem is really just like building a railway; it cannot be done out of revenue, it must be done out of capital both as regards the track (*i.e.*, roads) and as regards the rolling stock (suitable bullock carts).

I certainly support Mr. Murrell's resolution.

Mr. M. S. Duraiswami Ayyangar (Travancore) :—Mr. Murrell has in his paper brought to our notice in plain language certain facts regarding the difficulties which we are encountering in India on account of the inadequacy in the length of good roads ; has compared the same with Australian conditions and has come to the conclusion that since the bulk of the population of both these countries is agricultural, the key to the prosperity of India consists in our being able to eliminate steel tyres. While we ought to be thankful to him for bringing to light our difficulties, I for my part, and I hope many others also, will not be able to agree with his conclusions and with all that he says in his paper. He considers the pneumatic tyres for carts as great a national necessity as is water for irrigation and he advocates Government subsidising private owners to replace the steel tyres with pneumatic tyres. It has been argued that steel tyres cut the gravel and murum road, but not pneumatic tyred vehicles. As has been pointed out by Mr. Mitchell in his presidential address, the bullock cart has always been there as the primary means of transport of our agricultural produce and should take the first place in the agricultural country. The ordinary trip for the country cart for the greater part of its length is over unmetalled roads before the metalled road is reached and until we can provide better roads right in the villages we cannot expect the cartman himself to take the initiative of changing his cart so that we may be able to give him those better roads. It is axiomatic that pneumatic tyres require much better roads than what our unmetalled and village roads are at present and the initial cost which is necessary to bring about a change in them so as to enable them to take up the traffic of pneumatic tyres will be enormous. Looking at it from the point of view of an individual, the poor Indian *ryot* whose only asset is probably a cart or two, can ill afford to change it to a pneumatic tyre and bear the cost of replacing and maintaining them. In fact the main work for the bullock-cart is to carry the manure from his house or store to his field through rugged country roads. He does not

need a pneumatic tyred vehicle to do this The roads are not fit to take them and he does not really feel the change. Speaking about a small country like Travancore, situated in the south-western most corner of India, with an area of about 7600 square miles and a population of about 5,095,000, we are maintaining about 1200 miles of metalled roads at an average cost of about Rs. 450 a mile per annum, about 2400 miles of unmetalled road at an average cost of about Rs. 150 a mile per annum besides about 1500 miles of village roads and tracks maintained at a cost of a little less than Rs. 30 a mile per annum. We have also about 300 miles of canals and cross canals maintained at a cost of Rs. 250 per mile which facilitates the transport of our produce considerably. We have, besides, many lengths of petty village roads which are not under dapartmental maintenance, but are considerably used by the *ryots*. You will see from these figures that we have almost one mile length of road for every square mile of area in Travancore. The total cost of maintenance of these roads is about Rs. 10 lakhs and we are spending, on an average, about 8 to 10 lakhs more for the improvement of these roads every year. In the last official year, we have improved about 130 miles of roads and opened 22 miles of new village road. All this is as much as what a poor country like ours can afford to do for the development of its roads. Just imagine what it would cost to metal or otherwise modernise about 4000 miles of our unmetalled and village roads. I do not have before me a census of the number of carts available in our State, but I should say that it is not less than 2 to 3 lakhs. What would it cost to convert all these into pneumatic tyres?—the cost is stupendous. It may work to about 400 lakhs to improve all those roads and about 300 lakhs to replace the pneumatic tyres. Working this investment at a low figure of 4 per cent, it will mean an interest of 28 lakhs on the initial investment, and about 15 lakhs to maintain these roads every year—an expenditure of 50 lakhs every year against 10 lakhs we are now spending. Is this increased expenditure commensurate with the benefits derived? Can this be called reduction of expenditure? Is it a practical proposition?

Judging from the figures given above, I should say that Mr. Murrell's proposition to abolish steel tyres, basing it on his experience of Australia, would be a disaster to a country like India and if he still believes otherwise and he or any others were to rush through to register bullock carts and get this included in any Government scheme with a view to abolishing them, and if further, the States are also included under the future Federal Government, I can only say 'Save us from our friends'. I commend, therefore, the more moderate and practical scheme of Mr Lakshminarayana Rao of registering only the steel tyred carts that ply for hire

I should also like to mention a few. words about the soil erosion which he refers to in his subject and he advocates the elimination of the bulls in order to provide better pasture fields and more efficient grazing grounds without consequent disastrous effects of soil erosion. Here also I have to differ from Mr. Murrell in his advocacy of lessening the number of bullocks in the country, nor do I agree that soil erosion is caused by grazing Grazing of cattle over pasture fields helps to make grass grow, as half-bitten grass grows faster and prevents soil erosion rather than causes it At any rate, I should, on behalf of the severely worked and half starved bulls in India, request Mr. Murrell to be more sympathetic towards them and not aim at obliterating them totally

Mr. K. G. Mitchell (Government of India):—I should like to say a few words on this Paper because while listening to what has been said I

gathered the impression that some speakers had got hold of the wrong end of the stick, while others have seized on side issues. The right end of the stick appears to be this. The condition of rural roads is deplorable, something is wrong somewhere. Mr. Murrell's comparative study has suggested several things which he thinks are wrong and he has put them before us. We may not all of us agree with him all the way in his diagnosis or in every detail of his suggested remedies, but we all very heartily agree with him that the things that are wrong must be found out and exposed. I do not think that Mr. Murrell seriously intended any attack on the long suffering bovine population of India. Anyway, any change in numbers that would follow bullock labour-saving devices in agriculture or transport would be a gradual and natural process and is beside the question of this particular paper. I am sure, for instance that no member of this Congress would seriously advocate, the retention of the present inefficient bullock cart merely in order to employ two bullocks when one could do the work with a better cart. It would not, I suggest, affect Mr. Murrell's arguments one way or another if he expunged certain of his remarks about the bovine population, which certain members have taken to be as aspersions—as, for example, his remarks about grazing.

Then the last speaker, Mr. Duraiswami Ayyangar, said, I think, that before we could expect to introduce pneumatic tyred bullock carts it would be necessary to provide an extensive system of unmetalled roads for their use. That, I think, is to start a vicious circle indeed, because one of the greatest obstacles to an extension of the metalled road system is the recurring cost necessary to maintain it under iron-tyred bullock carts. The whole basis of Mr. Murrell's proposal is, I am sure, that with pneumatic tyred bullock carts our earth roads could be as good as those say, of America, while the cost of maintaining metalled roads would be greatly reduced and money would be set free for the extension of the metalled road system. The only way to get out of the vicious circle is to my mind to start improving the cart. To say that we must first multiply by many times the existing metalled system and hence the expenditure on roads is to put the cart before the horse. If you have got all that money to waste, you can afford to have the cart as it is if you like wasting money.

Now as regards economics I am tempted to join issue with our friend Mr. Joshi. He claims to know more about things Indian than people like me. I would venture to claim that it is not wholly inconceivable that I may know nearly as much about Indian roads as our friend. For example, when he says that the bullock cart does not want a metalled road, I would invite him to join the Public Works Department for a few weeks and to try to keep them off the metalled road and on a parallel unmetalled track. I think, he would quickly revise his ideas

To return to the general question of the economics. Bullocks have to be bred, fed and sheltered. There may be sentiment and other ideas repugnant to a reduction in the bullock population, but no one will convince me that there is any element of economic basis for the argument that we should, as I have already said, cling to an inefficient cart because it places us under the necessity of feeding two bullocks in the place of one. But this aspect is liable to be overstressed, and we do not know the facts. We do not know, for instance, what is the proportion of the total bullocks in India that is employed by professional cartmen solely on carting and what is the proportion of agricultural bullocks that only come on to the road in a cart occasionally at the time of carriage of the harvest to market. I have heard it said, I repeat that

we do not absolutely know the facts, that it takes twenty times the bullock power to raise and harvest a crop as it does to carry it to market. If that is at all true, it is obvious that, as far as the casual cartman is concerned, pneumatic tyres are not going to throw bullocks into the ranks of the unemployed. If it means a little less hardship and a little more rest—so much the better. The whole question is whether it is desirable that transport should continue for ever to be in a form of cart that is inefficient as machine and an obstacle to road improvement, or not. If it is to continue you are on the long run going to spend immense sums of money on roads, or do without better roads. Mr. Murrell is perfectly right in pointing this out.

Before I sit down, there is one thing I would like to say to my friend Mr. Joshi, if I may do so without giving offence where none is intended. He has told us that terrible suspicions of our motives have been engendered outside the Congress by certain of our proceedings and by passages in Mr. Murrell's Paper. It may be so, in fact I have little doubt that sometimes it is so. I myself became aware of this kind of suspicion when, a few years ago, I endeavoured to point out to the Congress that an extension of good road milage was more important to India than an increase in the unit weight of motor lorries, and that we should for this and other reasons have some limiting weight, for the generality of rural roads, to which to design. But our position is this. We say we want to improve the road-rupee ratio. On the purely road building side we are doing our best. But you can no more design a road without regard to the traffic that is to use it than you can design a railway without regard to the weight of the locomotives and rolling stock you propose to run on it. Therefore we have to consider the traffic and would be failing in our business if we did not point to what appears to us to be the avoidably destructive element in it. It is, if I may use a strong expression, little short of lunacy to say to an Engineer or to this Congress " It is your business to build and maintain roads—but you have no concern with the traffic that is to use them." We, in this Congress, cannot regulate the traffic, but it is our clear duty to tell those who can what a lot of money they have to waste because of certain features of it and what they could save by a modification of these features. That is our function and, thus explained, our proceedings need cause no suspicion to anyone. Mr. Joshi has told us of these suspicions. Having heard what we have to say may I ask him to tell his friends outside that they are groundless?

Mr. T. Lokanathan (Coimbatore):—This paper, dealing as it does with certain controversial points, is naturally full of certain *obiter dicta*. We need not be scared away by the more radical ones among these. We can leisurely look at them and see what we can make of them. I think we should be thankful to Mr. Murrell for having brought to the forefront the point which has been in the minds of road engineers *viz.*, the elimination of the steel tyre from the road. The problem has been confronting us, and we have not been able to find a solution. If statements are made in an exaggerated form, if hard things are said, we may put them down to the zeal of reformers. By a little thinking, we have now to come to practical conclusions. I will confine my remarks to the question of pneumatic tyres for bullock carts.

As was explained by me at the Bangalore Congress, it is the combination of the steel tyre of the slow moving cart and the pneumatic tyre of the fast moving motor vehicle that is proving ruinous to our roads. We can maintain a road for one type or the other, but we have found it impossible in recent years to make a road that will stand this combination of traffic. In Coimbatore, which is a dry district, we have to make use of carts for conveying water from fairly long distances for consolidation of road materials. We made a number of pneumatic tyred water carts, capable of carrying 400 gallons of water. The use of these carts cost us only half of what a motor lorry would cost, both as regards capital cost and as regards maintenance. This is a practical result derived from the use of both the pneumatic tyred carts and motor lorries. In the off season, the water tank is removed from the cart, and the cart is used for conveying road materials. Each cart fitted with pneumatic tyres can convey twice the material that can be conveyed in an ordinary cart. That is on account of the anti-friction device of the pneumatic tyre equipment. These carts were recently used in connection with famine relief work, and they had to go on all kinds of roads. We have found from this experience that the use of pneumatic tyres is not a deterrent to the use of the carts on all kinds of roads. I should say that a pneumatic tyres cart can go wherever a steel tyred cart can go. But on hill roads the steel tyred cart is found to go more easily. That is our experience.

The point is not that we do not want the bullock carts to remain in the country. The point is that we are only against the steel tyre of the bullock carts. Somebody stated that the use of pneumatic tyres is advocated by vested interests. The bullock carts came into existence at a time when the possibilities of rubber tyres were unknown. Now, that we have rubber tyres, some people say that the bullocks are dumb sufferers, because the pneumatic tyred carts are loaded with double the weight loaded on ordinary steel tyred carts. In Coimbatore we have 40 or 50 cotton mills, and almost all of them have voluntarily chosen to substitute pneumatic tyred carts for steel tyred carts. They put more load on the pneumatic tyred carts and yet the bullocks carrying them have not suffered, although it is five or six years since those bullocks have been made to drag the pneumatic tyred carts. To say that the bullocks are dumb sufferers is not correct. They do not suffer at all they are able to carry a bigger load owing to the pneumatic tyre equipment.

It has been stated that if a puncture occurs on the road, the cartmen will be helpless. But it is only a question of time. When pneumatic tyres become common, repair shops will spring up all over the country and even rubber tyres will be made in the country.

Mr. Ormerod (Bombay):—They are already made in India—Dunlop and Goodyear tyres are made in India.

Mr. T. Lokanathan (Coimbatore):—When demand increases, large scale production will come in and that will help to reduce prices also. When there is a larger demand for radio sets, we hear of the likelihood of radio sets being offered for Rs. 30.

We need not be deterred by frightening considerations. As road engineers, do we want the use of pneumatic tyres on the road or not? Of course, we need not shut our eyes to other aspects. We shall be

engineers, financiers and nationalists. Still we shall want pneumatic tyres if we are convinced that the roads are going to last longer thereby through the non-use of steel tyred carts.

I have made some experiments in the use of different types of axles. I have not yet got any results which are worth telling you, although the work so far done has been published before the Madras Local and Municipal Engineers' Association.

We have tried a road with 12 feet of granite water-bound macadam in the centre and 6 feet wide *kankar* macadam on each side. The bullocks themselves prefer these side tracks which are smoother. But this method of segregating traffic on the road, one for fast traffic and one for slow traffic is obviously impossible just now for financial reasons.

I should think that the railways ought to be able to convey agricultural products to the markets at a cheaper rate than country carts, becuase it is less costly to convey materials on a steel rail. Still we find that country carts are able to compete with the railways. This is a matter which requires investigation. If the heavy goods traffic is taken cheaper by the railways, then this traffic would not come on to the roads.

Mr. S. K. Ghose (Bihar):—I fully concur with the objects of this frank and fearless paper under discussion and also of the draft resolution, and I am optimistic enough to seriously believe that I shall some day visit the latest road developments in Australia and elsewhere, and serve my country with my expert knowledge.

I for one, do not believe in a sitting-on-the-fence attitude, and I honestly believe that India will shortly be manufacturing most of her own engines, motor cars, and aeroplanes, as well as all the pneumatic tyres, etc. required for the development of our National Transport system. I do not suffer from a defeatist mentality and when I took up the arduous job of surveying in the hills and jungles of South Bihar for preparing the Bihar portion of the Bombay-Calcutta Trunk Road project, I did visualise, as I do now, a brighter and better Trunk Roads system in India on the lines of the best system in the world (and I propose to be the first to come to Bombay by the proposed route!)

The days of bullock carts, as they are, are surely numbered, and it is for the progressive section of the engineers to improve upon the iron tyred Juggernaut,—which crushes under its thin steel edges India's highways and byeways,—by legislation and education of public opinion. The sooner the iron-tyred monstrosity disappears, the better will it be for India.

In connection with the development of India's roads, I must state with emphasis that the Indian Roads Congress should use its utmost influence through its members to induce the manufacturers to reduce the price of petrol, cement, steel, bitumen and tar etc., which are still being sold at enormously inflated prices. With the lowering of rates, and the consequent increased sales, their profits will remain as great.

The prevailing system in the Public Works Department of transferring engineers from the Roads and Buildings branch to Irrigation and so forth, is

surely most detrimental to the interests of public services as well as the country's highways, and the continuity of road policies and experiments are being rudely broken almost everywhere in India. This has got to be stopped, and the Indian Roads Congress should intervene in this very serious matter.

May I here put in two suggestions, even at the risk of appearing ludicrous? Firstly, in view of the absence of the expected general improvement of Indian roads which may be taken up after the present war is over, the Indian Roads Congress should recommend to motor-car manufacturers to keep the road clearance in some of the newer models to at least 9 inches, as in the old Ford until our road system is wholly modernised. Secondly, greater co-ôrdination with the public should be aimed at through the generous columns of the Press, to keep them well informed about the work of the Indian Roads Congress. For example, I would request that the present paper should be published *in extenso* throughout the length and breadth of India, to elicit public opinion and to receive further moral support in our crusade against bad roads and uneconomical methods of transport, which result in false economy.

Fearless papers like the one under discussion are required to clear up the mists of distrust and superstition which are retarding our progress. A bold Road Policy is needed for India as a whole.

Mr. V. R. Talvalkar (Baroda) :—If we consider some of our towns, the roads radiating from them outside into the country are being modernised in their surface treatment and also facilities for transport. Naturally all the traffic coming from the villages to these towns are being carried in motor cars and lorries. About 10 or 15 years ago I could not get a motor lorry to carry to my works in the City, bricks, sand etc. from outside kilns, and fields. But to-day I find that people have come forward to transport all these materials by motor lorries. So, the bullock cart is being gradually and naturally replaced by motor cars. If we follow this policy and extend it further, I think that in the course of 10 or 15 years more, the bullock cart will, by a natural process, be done away with.

Mr. W. L. Murrell (Author) :—I thank you for the reception you have given to my paper.

With one exception all speakers appear to have been helpful and constructive in their remarks.

There is but little time left, so I will have to furnish replies to most speakers in the form of correspondence to be published in the Proceedings.

I must mention now, however, that I agree that the first carters who should be made to use modified tyres are those who ply carts for hire.

Next, I agree that the tyres proposed to be substituted for the steel ones need not necessarily be pneumatic. They might be solid rubber or some other substance which investigation may discover.

Finally, I would like to assure Mr. Joshi that I am not antagonistic either to the bullocks or to the bullock carts in themselves. Ten years ago, writing in "Indian Engineering", I stated that "the bullock cart,

must still remain the red corpuscle in the life blood stream of India's traffic". I still stick to this.

I hope the resolution will be passed.

Mr. Murrell's Resolution and certain proposed amendments were discussed. The Resolution was finally adopted by the Congress in the following form :—

"This Congress, constituted by the leading highway engineers of the Governments and local bodies throughout India, and by the representatives of all the important highway construction and transportation interests

(*a*) Emphasises that, although roads are a Provincial subject, the similarity of the problems which they present throughout India makes them a matter of National importance. This fact appears to have been realised over ten years ago by the formation of the Road Development Committee, and by the creation of the Central Road Fund;

(*b*) Emphasises the supreme importance to the *ryot* and to agriculture generally of an adequate system of rural roads;

(*c*) Believes that progress in rural roads can be made by improving not only the road surface, but also the design and the loading of the vehicles that ply on them, and that the solution can be found without adversely affecting the economic condition of the villagers;

(*d*) Considers that the progress made in the provision of roads and bridges since the Report of the Road Development Committee has been wholly inadequate, owing chiefly to difficulties not foreseen and which could not be foreseen by that Committee;

(*e*) Considers that the time is ripe for a complete review of the whole position, and that such review is a matter of National urgency;

and to this end this Congress recommends to the Government of India that, in order to prepare for an adequate and progressive road policy after the war, a Committee representing different views, particularly with regard to (*c*) above, be appointed

(1) To examine the present position as regards roads in India, the extent of their inadequacy to the reasonable requirements of a modern nation, and in particular to the amelioration of the conditions of and to the social uplift of the rural population;

(2) To examine the progress made in other countries, and the administrative and financial means by which such progress has been achieved, particularly in the self-governing Dominions;

(3) To examine how far the steel tyre is an obstacle to progress and in what way that obstacle can best be overcome;

(4) To examine the question of improving the design and loading of the vehicles plying on the roads;

(5) To consider the present practices of road construction and maintenance in India with special regard to the best use being made of indigenous and local materials; and

(6) To make recommendations."

Mr. H. E. Ormerod (Chairman) :—Gentlemen, on your behalf, I thank the author of the paper. It has been an interesting paper, as must be evident from the discussion that it evoked.

CORRESPONDENCE.

Reply of Mr. W. L. Murrell, (Author) to the comments under " Discussions ".

As regards Mr. S. B. Joshi's remarks, it would doubtless be better to rely for my reply chiefly on the other speakers who rallied so promptly to the cause; but I must say that the very strong criticism was so very strong, that at times it almost even seemed offensive, and Mr. Joshi's final paragraph proved a most welcome and necessary sedative.

I thought over this matter for quite a long time after leaving Bombay, and this is the conclusion I have come to :—

Mr. Joshi subscribes to a party which I belive to be honestly aiming at the uplift of the Indian nation, though I confess I do not understand many of their actions. That party also professes to be genuinely in search of the truth.

I, therefore, hope that Mr. Joshi, with his undoubted ability and energy for thought and speech, will attend all possible meetings of the Congress in the future, and that he will mix more and more with all those of us Road Engineers who daily are really brought face-to-face with the problems that lie in the path of progress and uplift. In doing this he must come face to face with the truth, and the rest will follow.

In reply. to Nawab Ahsan Yar Jung Bahadur, I thank him for reminding my one completely destructive critic as to what is the real issue.

He also hit the nail right on the head when he stated and reiterated that we must all put our heads together and devise a means of improving the tyre of the bullock cart.

Rai Sahib Lala Fateh Chand sees that the destructive steel tyre is but a part of the picture, and that our first objective is the really sound organization of our administration. The acclamation that greeted his closing words "I say that there should be no labourers and coolies in our country, and for that we must raise their status" showed the real spirit that is behind our country, and Roads Congress. Our slogan is "Progress, and Peace and Prosperity through Progress".

Mr. Nurmahomed M. Chenoy mentioned the heart-breaking burden which the steel tyre places on India's road finances. If one were to pick up the "Annual Report on the Working of District Boards" for any Province, and total up the expenditure on the maintenance of even the

earthen, gravel, and brick metalled roads for that province alone, and then realise that these roads were getting worse in spite of all the expenditure, the magnitude of the wicked annual National waste that is going on throughout the length and breadth of India would become apparent.

Added to this, there is the destruction of surfaced roads whose life is reduced to $\frac{1}{3}$ or $\frac{1}{2}$ of what it would be without the steel tyre.

Mr. Dildar Hosain mentioned road and rail competition in Australia. In Australia, one state has tackled this problem by having a Commissioner of Road Transport and a Commissioner of Railways both working under the same Minister. In India, where railways are a Central subject, we might get a parallel organization by developing the Central Bureau of Public Roads.

It is true that the railways owned by the several states in Australia have suffered heavily owing to road competition in the past; but the public own both the railways and the roads, so what they have lost on the swings, they have made up on the round-abouts. Unfortunately I was unable to take advantage of a very kind offer to tour for a few days with the Railway Commissioner in his special train in one state; but I understand that, in the past few years, the Railway Commissioners have economised much by using special rolling stock on certain lines, by opening up feeder services by motor transport by road, and by capturing traffic through speeding up services and introducing many facilities for loading and delivery.

Thus the owner, the general public, really gains substantially by the road-rail competition, so long as the roads and railways are not over-capitalised, and when considering this, the country must consider that both works are also a vital part of defence measures.

In Hyderabad, they aim at getting dust-proof roads by making cement concrete roads. Most of us aim or will aim at making (almost) dust-proof roads by having earthen (stabilized) roads. The abolition or diminution of the use of the steel tyre is, therefore, our first necessary step—not a premature one, as suggested by the speaker.

I am afraid a description of the Australian road surfaces and the methods of financing them would take up many pages; but Mr. Hosain can get full information about these matters in the Annual Reports of the different state road authorities for the last three or four years, which can be had from our Congress Library.

Mr. Campbell Gray's suggestion to retain the axle and wheel of the bullock cart by placing the whole wheel within a rubber tyre, or by clamping on to the side of the wheel a sort of false felly and rubber tyre, is an exceedingly good one, and MAY LEAD TO A VERY GREAT REDUCTION IN THE COST OF ABOLISHING THE STEEL TYRE.

If solid rubber tyres are to be allowed, it will be necessary to make them very wide, as solid tyres do not distribute pressure *along* the road to any appreciable extent. We must not forget that our objective is largely to obtain stabilized earth roads, and that we must not, therefore, allow high shearing stresses in them.

As regards the proposed Central Bureau, if Mr. Campbell Gray will get Bruce's book, referred to on page 2 (j) of the paper, he will see that such a Bureau would have many functions in India, and that the eradication or diminution of the use of the steel tyre would be but one of them.

Mr. Lakshminarayana Rao is a critic I always like to hear. Madras is, I believe, the only province in India which has done the correct thing in provincialising her District Engineers, a measure of emancipation from a frequent local tyranny that is a great cause of delayed and bad road work in this country. Mr. Lakshminarayana Rao brings this freshness born of freedom to his speeches in this Congress.

He objects to the terms "Intolerable dictatorship" and "Survivor of the Dark Ages" as applied to the steel tyre plying between the village and the fields, with an occasional trip to the nearest town.

I concede that it is the 10 lakhs of carts that should be taxed; but it should be compulsory to register any cart that will ever come on to a public road. These "Occasional trips to the nearest town" on steel tyres would be the danger point or loop hole, not only because of damage to an earth-stabilized road, but because of the cover or chance given for pirating. For instance, cultivators frequently sell their produce in the local fair. The "buniya" or first middle-man gets them to fetch it in their own carts or in the carts of other villagers, to his godowns near the railway station. The same applies to the collection of sugar cane at railway stations or at mills.

It is hoped that my critic would not include all these journeys as "occasional trips to town."

Would it not be well if every cart which would never come on to a publicly maintained road would remain unregistered but painted (tarred) black, if every cart which were registered so that it could come on to the public road for an 'occasional trip to town' were painted red to indicate that it is a potential pirate, and if carts which were both registered and licensed were not painted at all?

As regards Rs. 18/- making a colossal difference in the budget of the poor professional carter, I really must ask Mr. Lakshminarayana Rao to get down to "brass tacks". Let him go to any place where there are a large number of fully laden carts—cane carts waiting at a weigh-bridge afford an ideal opportunity—and he will find that steel tyred carts are carrying from 14 to 18 maunds, while pneumatic tyred carts are carrying from 28 to 30 maunds. It will be noted that there is no difference in the kind of bullocks employed in either cart. In other words, by using the pneumatic tyre, the professional carter could increase his income by at least 50 per cent; so how can one think of a defecit of Rs. 18/- ?

Mr. Lakshminarayana Rao states that pneumatic tyres would cost Rs. 100 per cart (presumably with axle, wheels, and ball bearing hubs) and that solid rubber tyres would cost Rs. 16/- per cart—presumably with solid rubber tyres on the original cart wheels. I think these figures could be realised by mass production, and they can be fitted into the practical All-India problem of financing the improvement in the tyre.

A solid rubber tyre might not help much in traction, and it may make shear stresses too high for stabilized earth roads, but at least it would cause no damage to our present surface-treated water-bound roads.

And organized investigation may lead to other devices. What about impregnated Indian-grown fibres, or Indian felts? Molasses and bitumen mix to form something like rubber, and so on. Let us get experts on to the subject, and meanwhile keep an open and hopeful mind.

Mr. D. E. Gough's remarks are remarkable for their simple directness. "The purchase of pneumatic tyres for bullock carts is surely only another way of spending money on roads." "It is nothing short of insanity to spend large sums of money in making good roads, and then allow carts to smash them up." Nothing could be neater, or more true!

And if permanent world-peace would enable us to have some of that 7½ annas of the petrol tax and add it to some of the 2½ annas, to help those 40 or 10 lakhs of cartmen!

Mr. M. S. Duraiswami Ayyangar, I think, premises wrongly. He states that pneumatic tyres need better roads to travel on than steel tyres need, and, therefore, we should not have pneumatic tyres until we first improve our cart roads.

I would like to inform Mr. Duraiswami Ayyangar that pneumatic tyred carts will go wherever a steel tyred cart will go, and it will go there more easily. Also it will go in many places where a steel tyre cannot go, in among boggy fields, for instance, and over loose sand—places which break the hearts of bullocks and sicken the hearts of those who watch those shouting, prodding, and tail-twisting drivers!

As regards soil erosion being affected by over-grazing, I would refer Mr. Duraiswami Ayyangar to the circulars which are issued from time to time by the Central Board of Irrigation.

The remaining points raised by Mr. Duraiswami Ayyangar, I have dealt with in correspondence referring to other speeches.

But I would perhaps do well to repeat that I am all for the bullock cart.

My ideal is a cart with bulls that are not "severely worked," (because of modernised tyres), and bulls that are not "half starved," (because the owner will make enough profit to enable him to feed them properly).

As regards Mr. K. G. Mitchell's remark about my expunging my reference to the bovine population of India, I do not know exactly what should be expunged but, whatever it is, I would cheerfully expunge it!

Mr. Lokanathan's remarks constitute much technical information in a nutshell, and they should prove to be finally convincing to any roads Engineer who still had any doubt about the efficiency of what is, up to now, the most obvious form of improved tyre.

The remarks of Mr. S. K. Ghose, so full of optimism and reassurance are refreshing. Fortunately for India, there are very few in the Indian Roads Congress who believe in sitting on the fence.

The way in which the resolution was passed on the 12th December 1939 shows that we are all ready to get down on to our feet and push, if the administration of the country will make action even barely possible.

The matter of the "clearance" of motor vehicles is really one of supply and demand. Our efforts should result in making high clearances less and less necessary.

As regards publicity for the efforts of the Indian Roads Congress, we are not doing so badly; but it is by our hard work and unremitting attempts to achieve progress that this Congress will best and soonest become most widely known.

Since the conclusion of the Bombay meeting, Mr. Ghose has kindly invited my attention to the "Modern Review" December 1939 Page 717, to an article "The urgency of the Cattle problem in India" by Mr. K. A. S. Rao. I sincerely hope that Mr. Joshi will take the trouble to peruse this brief but very pertinent information.

Mr. V. R. Talvalkar refers to the possible complete ousting of the bullock cart by the motor truck in the not-so-distant future.

Personally, I think it will be many years before this replacement will be at all complete.

And this gives me the chance of making a point I should, perhaps, have made before.

Personally, I would prefer bullock carts with unshod bullocks and with pneumatic or solid rubber tyres on my gravel and unsurfaced water-bound macadam road. My experience, as I have several times pointed out before this Congress, is that self-propelling motor vehicles cause these particular surfaces to corrugate, whereas animal-drawn traffic has no such effect.

On such roads the only objections to the bullock cart are its slowness, which disorganizes traffic, and the carelessness of the cart owner who allows the bullock-shoes to get into such a bad state that the nails and thin sharp-edged remains of the shoes cause severe losses in time and material to the owners of motor vehicles.

So now the scratchy and patchy painting is practically complete in all its lighting effects so far as the bullock cart tyre is concerned.

The other three points discussed in the paper were :—

(*a*) Extensive re-organization of the administration.

(*b*) Increase of funds for road work.

(*c*) Improvement in technical education.

For these the picture is not so complete, for undoubtedly the steel tyre has been too magnetic a subject, and our attention has been largely diverted from the other aspects, and our time for discussion has also been very limited.

We have been informed that the matter of funds for road work is not really a concern of the Engineer, and perhaps the same applies to the matter of administration. Nevertheless, there could be no harm in collecting information, and in leaving it—sort of—'lying about.'

In other words, papers on these two subjects, as well as on possible means of improvement in our national system of technical education in road work, would be very real contributions to 'The Cause.'

Wednesday, December 13, 1939.

PAPER K—39

Mr. K. G. Mitchell (President) :—We will take up the discussion of Mr. Nilsson's paper on " Standardisation " and Mr. Syed Arifuddin will kindly take the chair.

Mr. Syed Arifuddin (Chairman) :—As Mr. Nilsson has not been able to be present here today due to indifferent health, Mr. Nicolaides will introduce the paper for Mr. Nilsson. I call upon Mr. Nicolaides to introduce the paper.

The following paper was then taken as read :—

PAPER No K-39.

STANDARDISATION.

BY

D. NILSSON, B. Sc., M. I. Struct. E.

Last year in Calcutta at the business meeting of the Roads Congress a recommendation was passed to the effect that the Secretary should arrange for type designs according to the Congress Standard Loading for reinforced concrete culverts and bridges up to 60 feet span. In this connection there was some difference of opinion and it appears that a short dissertation and discussion of standardisation in general would not be out of place.

The principal objects of standardisation are :—

(1) To co-ordinate the efforts of producers and users for the improvement and simplification of materials and methods.

(2) To simplify production and methods of use.

(3) To eliminate the waste of time and material involved in the production of an unnecessary variety of methods or of patterns and sizes of articles for the same purpose.

(4) To set up standards of quality and dimensions.

(5) To save time and labour and to give to all the benefits of the experience of others.

These objects are excellent, but in drawing up standard specifications, there are a number of pitfalls to be avoided and points to be watched.

The specification must be based on what is best in present practice, but no attempt should be made to obtain an ideal which might prove too costly to use, and would thus defeat its object. It must be such as to provide a general suitable standard of quality, dimensions, or performance and must also form an equitable basis for tendering.

To illustrate the last point, an example might be taken. A steel specification could be drawn up specifying the quality of the steel, what tests it should withstand and also its chemical analysis. This chemical analysis might be such as to enable one manufacturer, who had a certain source of ore available, to quote, whereas another manufacturer who produced just as good steel could not quote because his ore would not produce steel of exactly the same chemical analysis though it would produce steel of the same strength.

The specification should leave the producer as much freedom as possible in his methods of production and should also not interfere with individual initiative and invention. In this latter connection, it is generally wrong to attempt to standardise design which is the outcome of engineering skill and ingenuity. If designs are standardised the engineering profession will suffer by there becoming less necessity for engineers and by the stagnation that will set in. It may be thought that the best and most efficient design has been made, but science is always advancing and improvements occur both from the march of time and from individual skill and enterprise which will not be available if over-standardisation has been enforced. Standardisation must not be carried out merely to help the ignorant or lazy. A standard specification should, in fact, be confined, as far as possible, to questions of dimension and performance.

A good standard specification will, on the one hand, safeguard the purchaser by ensuring a generally suitable quality and performance at a fair price, and on the other, protect the manufacturers against unfair competition.

A standard specification should only be prepared when it fulfils a general recognised want and when both, producer and user, are prepared to co-operate so that both their interests may be protected throughout the work. There should be no coercion whatsoever by one section of the community over another section, as standardisation is arrived at by general consent. On such a basis over-standardisation will not be brought about and undesirable or unwise standards will not be forced on the community. Further, they will not prevent the purchaser, if he so desires, and is willing to pay the price, from obtaining special requirements

When a specification has been prepared, it must be periodically reviewed and, if necessary, revised to keep the work abreast of progress. A close watch must also be kept of the standard specifications produced in other countries so as not only to help in keeping up with the times but to even adopt those standards when suitable, thus gaining by the even greater distribution of the standard. It is obvious that the wider the adoption of the standard the better its effect.

Reference might be made here to the Roads Congress's own standard quite recently produced—the Standard Specification and Codes of Practice for Road Bridges in India. This ought to have been universally adopted throughout India, but unfortunately it is found that in some Presidencies it is not adopted or it is only partially adopted or it is adopted with various amendments. This attitude negatives the whole value of a standard specification. The greatest care must be taken in adopting a standard specification to see that it meets with the approval of all and it should not be adopted until the views of all interested parties have been heard.

Wise standardisation is one of the greatest boons enjoyed by the engineering profession and, it is suggested that, in order to assist in this connection, the Congress should join the British Standards Institution. This Institution is connected with the similar institutions in most other countries and many of its standards are accepted in other

Dominions or countries. Membership of the British Standards Institution would assist the Congress in its efforts to produce useful specifications for Indian roads.

Much of the matter in this paper has been taken from the "Aims and Objects" of the British Standards Institution.

The objects of standardisation are listed on the first page and in conclusion (*a*) the reasons for producing a standard specification and (*b*) the points to avoid in preparing such standards are also summarised.

(*a*) *Reasons for producing a Standard Specification.*

(1) There is a general desire on the part of both the producer and user for a Standard Specification.

(2) Both the producer and user are prepared to co-operate in forming a standard.

(*b*) *Points to avoid in preparing a Standard Specification.*

(1) Care should be taken not to make a specification such that it cannot be followed without increasing costs so as to make the produce unsaleable.

(2) The Specification must not be biased so that it only enables some manufacturers to work to it and others cannot although their products may be equally good.

(3) It must not reduce the producers' freedom or interfere with his initiative or inventive powers.

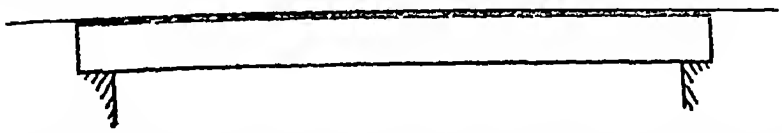
(4) No section must be allowed to force their views on others to the detriment of those others.

(5) The Specification must not prevent the purchaser from buying special requirements.

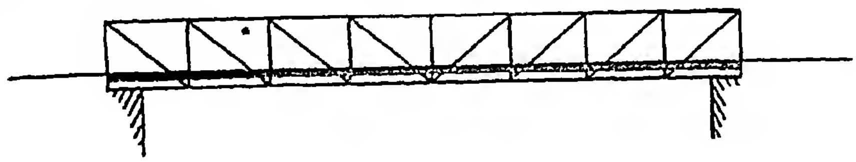
It, therefore, seems desirable that the Congress should hasten slowly in drawing up Standards and, in the initial stages at least, would be well-advised to confine themselves to Specifications of quality and performance rather than design.

DISCUSSIONS ON PAPER K—39.

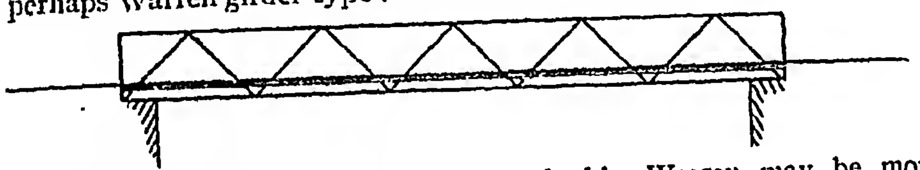
Mr. E. P. Nicolaides (Bombay):—The cause of this paper was the resolution passed at last Congress in Calcutta to the effect that standard designs should be prepared for culvert and bridge spans up to 60 feet. I hope the paper has shown how wrong such a procedure would be, but I wonder what the supporters of the resolution really expect to get. Is it the details for an ordinary beam and slab design?



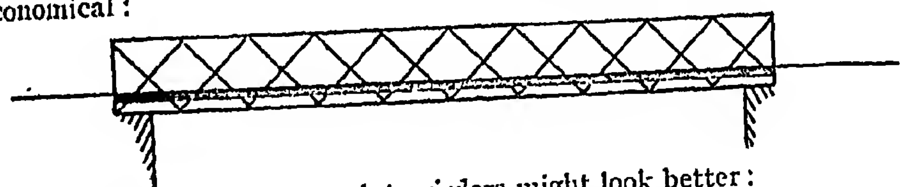
But I think our friends from Madras would prefer steel girders perhaps of ordinary N design:



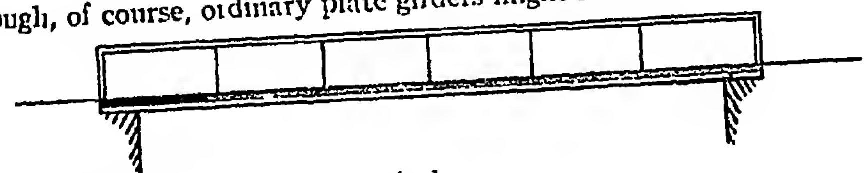
or perhaps Warren girder type:



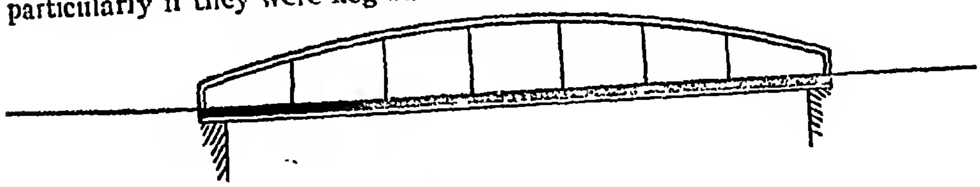
or if light sections are cheaper, the double Warren may be more economical:



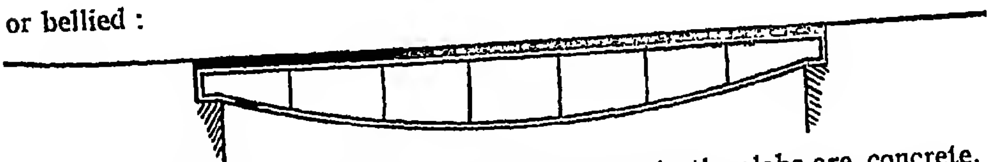
though, of course, ordinary plate girders might look better:



particularly if they were hog-backed:

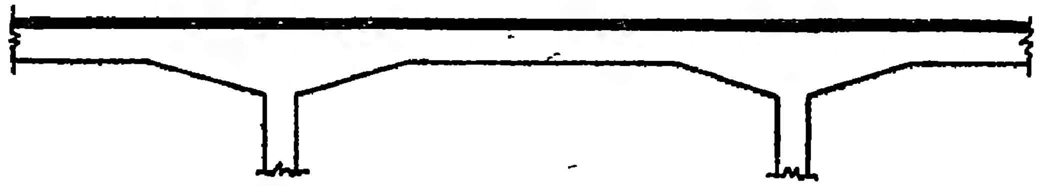


or bellied:

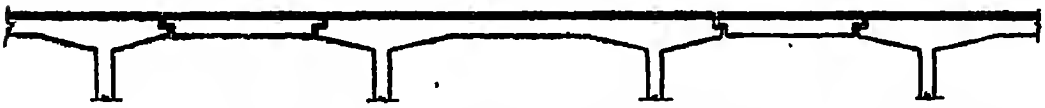


but Mr. Ormerod would probably object, as only the slabs are concrete. Then we should have to fall back on the North West Frontier's liking

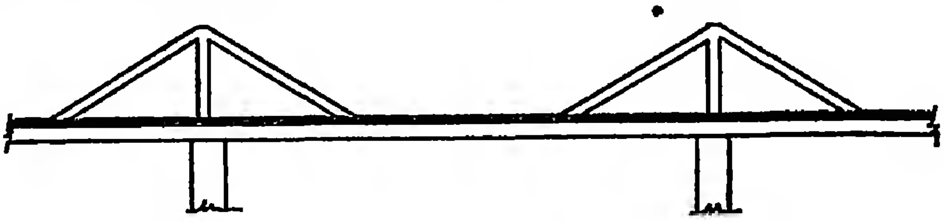
for continuous haunched Reinforced Cement Concrete beams with Reinforced Cement Concrete slabs :



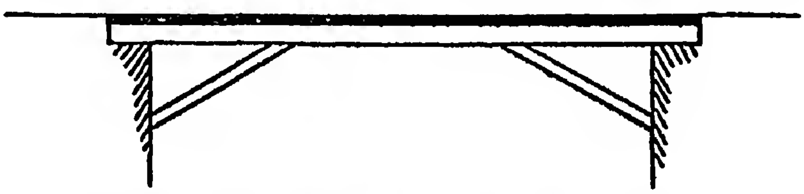
though, of course, here Dr. Korni would ask for a cantilever design :



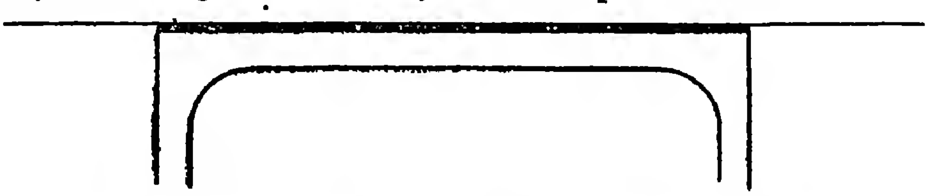
whereas the engineer from Charsadda (N. W. F. Province) would say he has an extremely cheap design of steel joists and Reinforced Cement Concrete Slab :



though in Kashmir and the hills this would be turned upside down :

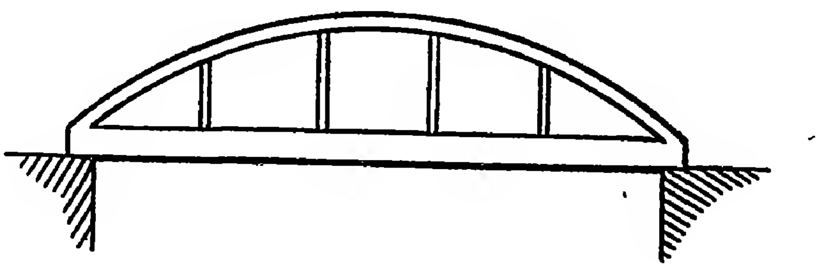


Again, frame designs have recently come into prominence :

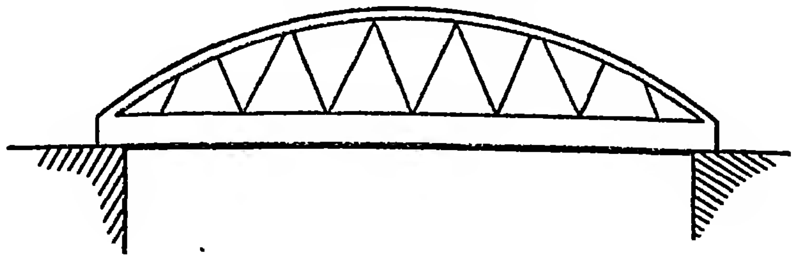


and the tea-planters in the Duars will soon approve of Bengal's Reinforced Cement Concrete slab type portals :

but if we go down south again to Travancore, they will prefer bowstring girders :



though in that case I should prefer to have inclined hangers :



but this is bringing us near arches and I could fill much more space with arch-types and I think you have enough examples here already. Each one of those types will be the most efficient in some particular site, but no one type will ever be the most efficient on all sites.

A glaring example of over-standardisation is the Madras Detailed Standard Specification* where the producer's initiative and inventive powers are interfered with, and where one section forces its views on others not only to the detriment of those others, but to its own.

Though designs are not standardised, methods of design are, though those methods are completely out of date. But in spite of being so out of date, only within the last couple of months, we have been forced to use the specified Bending Moments of $\frac{W\,L}{8}$ or $\frac{W\,L}{12}$ etc., and the theorem of Three Moments would not even be considered, let alone accepted.

In the paper I have stated that the Indian Roads Congress Code is not universally adopted in India, and as some of you may only know what is used in his own Presidency I may mention that at least up to a few months ago Bombay, Madras, Assam, Orissa and Bengal are some that had *not* adopted the Code Loadings. Bombay used B.S.L. x 12 plus 50 per cent impact ; Madras has Classes A and B made up of rollers and uniformly distributed loads; Assam a 10-ton Roller plus 25 per cent impact and 80 pounds uniformly distributed; Orissa a 12-ton roller and a 5-ton lorry and 85 pounds per square foot; Bengal 10-ton roller plus line of 6-ton lorries plus a uniformly distributed load. Those figures are only from memory and I am open to correction but my point is that this very large portion of India did not adopt the Code it helped to make. Will it use type designs based on different loadings to what it now uses ?

Mr. W. L. Murrell (Bihar) :—It seems to me that the Author has not differentiated sufficiently between the standardisation of design, and the standardisation of specification.

Let us consider the former first, as the question of adopting type designs is now up for decision.

It appears that after giving five good reasons for having standardisation of design, the Author gives only two reasons against it.

The first reason is diminution in the number of Engineers. This applies much more, of course, to the staff employed by large Engineering contractors than it does to the staff employed by Governments or local bodies.

As regards the great majority of Engineers in India, *i.e.*, those employed by Governments and local bodies, these Engineers are indispensable for field work and supervision, and bridge design forms but a small part of their duty, so they would remain unaffected.

We would be sorry to see large Engineering firms putting off their designers, as type bridge designs had been evolved; but this is scarcely probable as road bridges are not the only structures dealt with by such firms.

The other reason given by the Author against the adoption of type plans is that there will be no improvement in design as time goes on.

There would be a great deal in this agrument if the adoption of type designs meant that tenderers were absolutely forbidden to submit alternative designs and tenders along with their tender for the type design. But surely this is not the intention of the Roads Congress.

The five reasons given by the Author for the standardisation of design seem greatly to outweigh the two reasons given by him against it.

Speaking personally, I have had a good deal to do with road development projects in the past 2 or 3 years, and the District Boards and Public Works Department Officers concerned have had to work with insufficient and inexperienced help. We simply could not have got through the work if the Government of Bihar had not issued design instruction sheets (type designs) for all classes of culverts likely to be required in any road project.

As regards standardisation of specification, the Author seems to give many reasons for its adoption and not one against it. Points to be avoided when proceeding are certainly not reasons for not proceeding.

I think it would have been a very fine and helpful paper if the last paragraph about making haste slowly had been omitted; and that is all I have to say on the paper itself.

It occurs to me that there is a matter of general interest to the Congress which might be touched on here. I refer to the way in which the Council gets out a standard specification without first getting it approved by every single member of the Congress.

For example, our Standard Specification and Codes of Practice for Road Bridges.

When the specification and code came suddenly before the general meeting as an accomplished fact, there was quite a disturbance. Amongst many members, feeling against the Council ran pretty high and, if the Council had had their garden party that day their buns might have been used in evidence against them. I, personally, was as indignant as anyone.

I see now, however, that if those who were pushing the specification through had waited for general approval, we would never have got the specification in 100 years.

What we have is most useful and, with an annual tinkering, or periodical review as the Author calls it, some day even the die-hards will embrace it.

This, then, seems to me to be the principle we should work on in our standardisation of designs and specifications.

Let us get something reasonably good to start on, something to help the great majority of Engineers even if it will not help the few very critical specialists or experts.

Unless we follow such a line we will never get any start at all.

The faults in what we first get can be dealt with in papers by members.

A good slogan for this Congress would be "GET ON WITH IT".

Mr. S. B. Joshi (Bombay) :—I endorse every word in this paper. The author is right in presenting this paper before the Congress. The main object of the author is to persuade the Congress not to issue standard designs up to 60 feet. I would give the instance of the Associated Cement Company, who have issued tables for designs of lintels and such other small things in buildings. Whenever such standard designs are issued, our engineers really grow lazy, as the author says on page 2 (k). In the last paragraph on the same page, the author says :

> "Wise standardisation is one of the greatest boons enjoyed by the engineering profession, and it is suggested that, in order to assist in this connection, the Congress should join the British Standards Institution."

I would suggest a better method—the establishment of our own Standards Institution. We, on behalf of the Institution of Engineers, (India), will surely move the Government of India in this matter, and we request the authorities of the Indian Roads Congress to co-operate with us in this matter.

I again endorse the suggestion which the author has made in the last paragraph, namely, that the Congress would be well advised to confine themselves to specifications of quality and performance rather than design.

With regard to the Indian Roads Congress specification, I would suggest that in addition to prescribing a uniformly distributed load plus a knife-edge load, the specifications should also give an alternative loading of an equivalent train of loads.

Rai Sahib Lala Fateh Chand (Bijnor) :—I think standardisation is very necessary, because it will save a lot of time and labour if we are equipped with all sorts of designs.

It may be said that we cannot adopt the same standard for different places and different climates. This Indian Roads Congress standard specification is not meant to be adopted under all circumstances. There are certain points which are similar in all places, and to that extent it will help us a great deal if we have some standard specifications and tables laid down by the Indian Roads Congress. For instance, manufacturers lay down certain standards about the quality of cement, the quality of steel, and so on. There are the British Standard Specifications also.

I would stress upon one point, and it is that there should be periodical review, as the author has suggested, and the specification should be adopted after full discussion and after hearing the different points of view.

Mr. Syed Arifuddin (Chairman) :—If nobody else is going to speak, I should like myself to say a few words in connection with this subject.

I find that there is a difference of opinion on this subject of standardisation, but the difference really does not lie actually in the question of having standardisation, but in limiting it to certain points.

The object of this paper seems to me to be threefold. One is to impress on the members of the Congress the importance of standardisation; secondly, to guard against over-standardisation; and thirdly, to explain the objects to be kept in view I would include as an important object of standardisation the completion of a work with least amount of strain on the mind, in the shortest possible time, with maximum accuracy consistent with necessity. It is fundamental in every administration and, in fact, in every work that there should be the uniformity of thought and action. All the laws in every sphere of human activity are meant to achieve this object. When laws and rules are followed in a dogmatic manner without understanding why they are framed and when and how they have to be complied with, the whole spirit is gone and the work becomes purely mechanical. Their utility must necessarily be reduced and they begin to be misused. Because of this defect we cannot avoid making laws. Similarly we cannot say that standardisation should not be done. In fact, there is no department in which some rules or some standard way of working does not exist. But it is very important to understand where standardisation or formation of rules should stop and where individuality must assert itself. It is very difficult, if not impossible, to find a hard and fast line of demarcation. But still we must try to find some general rules to test our standardisation work.

As far as engineering work is concerned, all standardisations may come under one of the following three kinds:—

(1) Specifications, including the quality of material required and the purpose it has to serve.

(2) Design.

(3) Method of working, which includes all classes of work, such as office work, field work, estimating, etc.

In the matter of specifications, it is very important to mention very clearly where it has to be used and under what circumstances a deviation is permissible, and within what limits. It is also necessary that specification must cover as far as possible all practical conditions which are prevalent. It is not worth spending time in including rare sases. For instance, if by limiting the maximum widthof joints to ½ inch, the stone masonry costs Rs. 40/- per cubic foot, it is necessary to specify the nature of works where this class of masonry should be used. If the cost of masonry be reduced to Rs. 30/- by increasing the maximum width of joint here and there to 1½ inches, it is necessary to include it also and specify its uses Certainly there are a number of masonry structures where it is waste of money to use the former superior class of masonry. The absence of the latter class of masonry will make standardisation incomplete and will result in wasting money if strictly adhered to. On the other hand the inclusion of a very high class of ornamental dressed stone work which is very seldom used will bring it under the category of over-standardisation Such items ought to be left to the individuals designing them.

In the case of specifications, the tests will be whether any particular item fulfils the objects mentioned on page 3 (k) of the paper, and in addition to it, it is necessary to see whether its inclusion is going to fulfil a general demand or whether it refers to works which are rarely done.

With regard to the design and the method of working, the objects of standardisation are :—

1. Saving of time by avoiding repetition.
2. Reducing the chances of error which must be high if the same thing is designed over and over again by different people.
3. To create uniformity of views.
4. To reduce the strain on mind.

Even here, the important point is that the standardisation must apply to those items which are often required in practice and not to rare things.

I would like to mention some of my experiences. When I was entrusted with the work of aligning and estimating the Nizamsagar Canal and Distributaries, I felt that want of uniformity of ideas was hampering the work and wasting a good deal of time of every member of the party : the result also was not satisfactory. I thought over the problem for several weeks and ultimately drew up certain definite methods of investigation and acquainted all the officers and subordinates working under me of this procedure. I did not want them to follow any set rules without understanding them. In fact, this method taxed their ingenuity and power of thinking to the fullest extent, but saved their time and saved also the strain on their brain. For this purpose a number of statements were made and provided for and a definite way of thinking was developed. In this manner, every member of the party was made to concentrate his attention on particular points in a particular manner, keeping all the possible alternatives in view. This brought to light the various alternatives correctly in a short time, and without much strain on their mind. In the first six months I could align only 10 miles of canal with a great deal of worry to me and other members of the party. The subordinates were of very little use to me in the principal part of the work. But when the new method was understood properly, I could align 60 miles during the next six months. I may mention here that the country was one of the most difficult for canal alignment, consisting of forest and hills. Similarly, during the first three months, when the party started working on distributaries, we could not complete more than about 50 miles of distributaries, but during the next period of nearly six months we aligned and surveyed over 400 miles of the same.

For estimating I had to do something of the same kind. On testing I found that to estimate 3 miles of earthwork according to the usual manner one person required three days, and it also necessitated a check by another subordinate, otherwise a number of errors would have remained uncorrected. After spending some thought over the problem, I prepared several tables and devised a method of doing this work. On the very first day I myself completed the estimate of nearly 2½ miles and it became quite easy after a few days' practice for every one to complete 3 miles per day. On having the work checked, I found that the errors were so few and of such minor nature that it was unnecessary to get the

work done checked. So, the estimating of canal and distributaries came up to the standard of mass production; the time was reduced to $\frac{1}{6}$, the strain was reduced considerably and the accuracy was increased considerably. Similarly, the method of estimating masonry works, including bridges, was modified so that a person could prepare estimates of 2 to 3 masonry works per day quite easily and without error and without drawing a single masonry work. Cyclostyled sketches of type designs served my purpose. The individual designing and drawing was limited to about half a dozen structures. The detailed drawings were done at the time of construction. The fact that everybody understood why and how the methods were arrived at helped the work very much. With some practice many overseers could do the work which originally had to be done by officers.

From these facts, I came to the conclusion that in the work that we are called upon to do, it is much better to have some common way of thinking. I found that not only time was saved but also better understanding was achieved. The result of it is that if the standardisation is done properly and is utilised properly, it, instead of making people work mechanically, increases their efficiency as well as their knowledge. It all depends on how we practice it.

I do feel that intelligent standardisation is very essential for every work. I have some experience of failure which resulted from the making of rules which, instead of achieving these objects, went exactly the opposite way, simply because instead of saving time we had to make the persons do so much work in the hope of obtaining some efficiency which even when achieved was very small, that it actually retarded the progress of the work. I do not want to waste the time of the members of this Congress by narrating all these experiences. I have mentioned the above facts simply to impress the importance of standardisation. I feel that it should be adopted not only in the case of specification but also in the case of designs, and, if possible, in the methods of work as well. If we achieve this result, we will have done a great deal, and I think the Congress will be able to congratulate itself on having saved the time of thousands of our officers and at the same time increased their efficiency.

The author will give his replies in writing.

CORRESPONDENCE.

Comments of Mr. Dildar Hosain, Hyderabad-Deccan.

The author seems to have treated the question of Standard designs and specifications on the same plane and both of these are grouped under the head standardization. As every Engineer knows, a standard specification is generally a schedule or in other words, statement of the qualities that are to be fulfilled by a material or materials before they are used in the Engineering Constructions. This is obviously based on the accumulated experience of a long time in Engineering matters. It might happen that due to fresh discoveries in science, a few details may have to be altered here and there, but as the fundamental properties of materials remain the same, it seems scarcely necessary to consider a revision in the specifications from time to time as suggested by the anuthor. At any rate in the case of things found in nature, for instance stone and timber etc., no radical

changes in the specifications are likely to occur. In the case of manufactured articles, such as cement or steel, the specifications might be susceptible of revision, but it is obvious that even in these cases, the advance made in the manufacturing methods would not be so marked as to need a revision at shorts intervals. Therefore, until such time as any radical change in the specifications is claimed by the manufacturers and accepted by the general Engineering practice, it is hardly necessary to leave the door open for confusion by leaving the specifications flexible and liable to alterations according to individual opinion The specifications laid down with regard to the quality of a work or a material do not by any means impose a limitation on the ingenuity of the producer, as the author seems to think. Every producer strives, from the commercial point of view, to produce articles which have the best of the qualities capable of withstanding competition in the market. The Engineer on the other hand, being responsible for the public money, is anxious to obtain the best return for every rupee invested in the purchase. He must, therefore, have certain standard principles on which to judge the merits of an article. For this purpose the standard specifications are necessary. They cannot, therefore, be confined merely to dimensions and performance as suggested by the author. Specifications would fail to serve their purpose if they do not specify the requisite qualities as a preliminary to the performance expected of an article or articles.

The next question is about the standard designs. Standard designs in the case of road works represent, as every one knows, the types of the various culverts and bridges most commonly adopted on the roads. The object of these designs is that in case any one of them is found necessary, the calculations and the details of dimensions and quantities should be readily available. The author has stated in one place that one of the objects of standardization is to eliminate the waste of time and material involved in the production of an unnecessary variety of methods or of patterns and sizes of articles for the same purpose, but in another place he says that if designs are standardized the Engineering profession would suffer by there becoming less necessity for Engineers and by the stagnation that will set in. These observations do not reconcile with each other. Standard designs are neither the instrument for the lazy or as the crutch for the ignorant to lean upon. They are merely labour saving devices, intended purely to simplify work. Standard designs do not bind an Engineer to adopt only one particular type but to adopt one out of the different possible types, depending on economy in cost. For instance a valley might be capable of being bridged with 2 spans of 60 feet or 4 spans of 30 or 6 spans of 20 feet The Engineer has to use his judgment in designing the most important part of the work, the waterway. Having fixed this, it is for him to select the most economical design consistent with the local conditions. Standard designs are not, therefore, intended to kill or paralyse the ingenuity of the designer, nor are they likely to reduce the number of Engineers. On the other hand they would save the tax payers money that would be otherwise frittered by the waste of time due to each Engineer working out elementary designs from the first principles.

It may perhaps interest the members of the Road Congress to know what has been our experience in Hyderabad.

During the course of the scrutiny of several hundreds of estimates of road projects, it was noticed that the design for the same kind of

culverts often differed in different districts. This was partly due to the different methods employed by the Engineers concerned and partly to the absence of the uniformity in the considerations of fundamentals. The result was that, when the designs after passing through the district offices and the offices of the Superintending Engineers, came to the office of the Chief Engineer, considerable correspondence had to be carried out which meant loss of time and energy. Occasionally it happened that in the calculation of quantities there were serious omissions and each office had to spend a good deal of time in arithmetical checking.

Owing to the time required for preparing and checking the estimate for each masonry work, the staff in each district office was overstressed with work and the district officers complained of the shortage of staff.

With a view to avoid the repetition and the duplication of the work and the consequent dissipation of energy, it was considered necessary to introduce standard designs for the masonry works which are most commonly constructed on the roads. The work is on hand for the past two years and is being carried out in accordance with the Code of Practice of the Indian Roads Congress.

2. Comments of Mr. M. Mahapatra, (Sambalpur.)

It is admitted that the Standards should be practicable and should be reviewed periodically. The points advocated by the author are :—

(1) The standard should be based on the best in present practice,

(2) be such as to give free scope to the designers,

and (3) be such so that it can universally be adopted.

It is also pointed out that the Standard Specification and Codes of Practice for Road Bridges in India prepared by the Congress is not being followed in many provinces which is also true. It is really useless to have standard specifications and designs which will not be followed. In this connection I may be excused to point out that the non-adoption of the Standard Specification is the fault of the respective Engineers who even knowing the existence of such specification on account of inertia still like to follow the specifications and type designs in vogue before the standard specification of the Congress came to light. As majority of the Engineers of Governors' provinces and local bodies joined the Congress, the knowledge of existence of the specification cannot be denied nor anybody has yet pointed out any clause in the specification as not suitable to any province. It is not being followed because the old specifications and designs have not yet been superseded. Even in a particular place, different working stresses are being adopted for the same type of work. To avoid such uneconomical and different designs, standard type designs for culverts and bridges are necessary. By this the scope of the designers will in no way be limited nor the new inventions be prohibited. There is only one danger, that is, the secrecy of designs will suffer. As a matter of fact the principle of designs should not be a secret one. It should be made clear to the purchaser at whose cost the design is experimented and put in practice. Now coming to the point of standardisation :—

(1) In my opinion the specification should be to produce an ideal work so that the present practice can improve by its enforcement.

(2) *Margin for the designers:*—The main points of design for quality and performance should be standardised leaving the minor points concerning out-ward appearance to be arranged by the designers to give an artistic view.

(3) *Universal adoption of the standard designs:*—As soon as the type designs are prepared the bridge specifications will be automatically followed. When the Chief Engineers of provinces accept the specifications of the Indian Roads Congress, there will be no difficulty in its adoption if a Circular to the effect is issued.

3. Reply to the discussions by Mr. D. Nilsson, (Author).

When writing the paper I felt that Mr. Murrell would be the first to criticise and I was right. His remarks are welcome but I cannot help feeling that he has to some extent misunderstood the paper. The five objects of standardisation given in my paper cover the standardisation of materials, methods, dimensions and quality, but I particularly mention that it is generally wrong to attempt to standardise design as design is the outcome of engineering skill and ingenuity. Further no reason whatever is put forward by me in favour of the standardisation of design.

Mr. Murrell says the majority of engineers in India have little to do with bridge design. Then why force them to do things of which they have little knowledge ? A little knowledge is still a dangerous thing. We all have a little knowledge of medicine, but when anything serious happens, we call in a Doctor—an expert. And further when we have to undergo an operation, we do not go to the Doctor who quotes the cheapest price but to one in whom we have confidence. Why is it that in India the only professional men that can expect payment for their knowledge are doctors and lawyers ?

Other countries find that it pays them to employ experts on various engineering subjects but in India advice and help are expected free and the strangest thing is that it is generally engineers themselves who particularly object to paying for a specialist Engineer or Architect.

Mr. Murrell agrees that if type plans are adopted, there will be little improvement as time goes on unless alternative designs are admitted. Let me assure Mr. Murrell that where type designs exist, it is almost impossible to get alternative designs considered, and do not forget that although many may be striving for stagnation here, elsewhere science is advancing. For instance have you heard of Pre-Stressed or Treated Concrete ? It has already been used in some very large works and involves stresses in the region of 140,000 pounds per square inch in the reinforcement, and strengths of 5000 pounds per square inch developed in the concrete in 2 hours. Such figures may appear rather fantastic but they are in practical use and the process is, of course, only used where it provides a more economical solution than ordinary concrete or steel can provide. I hope to be able to use it in India at no distant date.

Mr. Murrell seems to be under the impression that I am against standardisation in general, even of specifications, but I do not see how he can obtain any such idea from the paper. On the contrary I am doing my best to advocate standardisation of the correct things and I trust our

New Council will adopt the suggestion in my paper that we should join the British Standards Institution.

I think Mr. Dildar Hosain has been doing some confused thinking and should re-read the paper as in the first part of his remarks he imputes certain statements to me which I did not make. He also says that it is not necessary to consider revision of the specifications from time to time and that the advance made in manufacturing methods would not be so marked as to need revision at short intervals. In this he is quite wrong, and to quote his own examples of cement and steel, the British Standard Specifications for these were revised and added to in 1906, 1912, 1925, 1929, 1930, 1931, 1932, 1934, 1936, 1938, 1939 and even then some of the revisions were much overdue. In the foreword of each British Standard Specification is written "Suggestions for improvements, addressed to the British Standards Institution will be welcomed at all times. They will be recorded and in due course brought to the notice of the Committees charged with the revision of the Publications to which they refer."

Mr. Dildar Hosain later in his remarks dealt with design, but I do not think his idea of design is the same as mine. He includes culverts in design, but I assume design is something that will be the outcome of engineering skill, technical knowledge and ingenuity and I do not think that much of any of these is required for culverts. I certainly think that type drawings of culverts will be useful, in fact almost essential, though I think these should be prepared by the various Provinces to suit their local conditions and I doubt if it is the Congress' job to prepare them.

He then goes on to suggest that when a valley of 60 feet has to be bridged the engineer should choose between two type designs of 30 feet or three of twenty feet. Given type designs that is just what will happen and what does happen, and is one of the most dangerous disadvantages of having such designs. In 90 per cent of the cases neither of these layouts will give the cheapest arrangement and the tax-payer's money will be wasted. Even for such a small valley dozens of arrangements could be made and most of them will be cheaper than the multiple type design bridge

I have to thank Mr. Joshi for his support and I think his suggestion of forming an Indian Standards Institution is an excellent one. Such an Institution would not only deal with the road works but all sorts of Industry from Mills to Mechanical Engineering or from Iron to Illuminations. It should, however, become a Member of other countries' Standard Institutions in order to benefit by as wide an experience as possible. In the meantime I still think the Indian Roads Congress would benefit by joining the British Standards Institution.

Mr. Mahapatra says "the secrecy of designs will suffer". Let me assure him there is absolutely no secrecy in design. The technical knowledge is to be found in Colleges and in books for all who wish to learn. Having acquired that knowledge all that is further necessary is experience and ingenuity.

From the Chairman, Mr. Syed Arifuddin's initial remarks it appears that he has fully grasped the purpose of the paper, but later I think he rather confuses Standard Specifications for use throughout the country and Local Specifications and the organization required for particular works.

For instance the example of ½-inch or 1½-inch joints in stone masonry is not a matter for a Standard Specification. In some places, ½-inch joints are required, in others 1½-inch will do and each case requires a separate local specification. Similarly the organization of the work at Nizamsagar was a local matter for the officer in-charge to arrange and Mr. Syed Arifuddin has done it very effectively.

I do not agree with him when he states an important object of standardisation is to save strain on the mind. Except for the old, mental work (not worry) can never do anything but improve the mental power, knowledge and experience of the individual.

Mr. Syed Arifuddin says that "when laws and rules are followed in a dogmatic manner without understanding why they are framed and when and how they have to be complied with, the whole spirit is gone and the work becomes purely mechanical. Their utility must necessarily be reduced and they begin to be misused". With this I entirely agree and this is exactly how standard designs if prepared will be used. I have said in the paper that standardization cannot be carried out merely to help the ignorant and lazy, and I repeat it.

Four objects of standardisation of design are given by Mr. Syed Arifuddin and as regards the first "Saving of time by avoiding repetition" I might say that in our experience of the design of many thousands of bridges (I am not speaking of culverts but have returned to the cause of this paper) it is very seldom that we can take a design off the shelf and say that it will suit. Admittedly it might very often be possible to use a previous design on a new site but it is very seldom economical.

His second object is the "Reducing of chances of error," but as a design seldom proves economical on two sites, I think that individual design will reduce the chance of mistakes and wastage. His third object is "To create uniformity of views" which as far as design is concerned I think leads to stagnation. The fourth I have already dealt with. He then says "the important point is that standardization must apply to those items which are often required in practice and not to some things." But the fact is that given standard designs of small bridges these are used by repetition, most uneconomically, to cross large rivers as can be seen by the glorified culverts which are often found crossing rivers of 1000 feet and more in width. It is you and I and all the other taxpayers from the humblest *ryot* to the wealthiest industrialist who has to pay for this waste of money.

In conclusion there is one point which I do not think was brought out in the paper and which might help to clear the subject, as apparently there is much confusion of thought on how, why, and particularly what should be standardised. The British Standards Institution, though it receives a Government grant, could not exist except for the voluntary support of Industry, Professional Institutions and Trade Organizations. This support would not be given unless Industry, Trade and the Members of the Professional Institutions actually save money by the standardization. Thus there does not exist any British Standard Specification for designs of bridges or even culverts or in fact designs for anything, but there are British Standard Specifications for about 1000 different materials, processes, dimensions of articles, and qualities of materials.

PAPER I—39

Mr. W. L Murrell (Chairman):—I would call upon Mr. D. C. Datta to introduce his paper " Slip and Subsidence in a hill road "

The following paper was then taken as read :—

PAPER No. I-39.

SLIP AND SUBSIDENCE IN A HILL ROAD.

BY

DHIRENDRA CHANDRA DATTA.

Assam Engineering Service.

Slips and subsidences are of common occurrence in a hill road, but in the Dimapur-Manipur Road, they are very common and exceptionally heavy, on account of the very steep side slopes and the nature of the soil which is in the process of disintegration. This paper primarily deals with conditions of the Naga Hills, as nearly half the length of the road passes over Naga Hills District. The annual rainfall in the locality is not unusually heavy, but its intensity is rather high compared to its duration.

Originally, the Dimapur-Manipur Road, which is the only means of communication between the Manipur States and the Naga Hills with other districts in the Province of Assam, was meant for carts. It had a narrow track with earth surface, steep gradients and very sharp curves. With the increase in traffic and adoption of modern means of transportation, it has been found necessary gradually to widen, realign and metal the road surface, and ultimately, to suit the requirements of the present fast vehicular traffic, the metal surface has been painted with bitumen or Tar. In the course of this transition, greater area had been exposed to weathering effects and the chances of erosion increased.

Land slide and subsidence take place when the static balance within the soil is disturbed, due to loss of friction or removal of back support at the bottom of the slope. When the soil is not impervious, rain-water soaks in and reduces the co-efficient of friction, and if there be subsoil drainage, or seepage, the portion above that zone, being unbalanced, slides down. Soil containing soluble salts is most treacherous in this respect. In certain localities of the Naga Hills, soil consisting of blackearth and shale, is very rich in soluble salts, mostly sodium and calcium, which readily dissolve during the rains and the soil is lubricated, as it were, reducing the co-efficient of friction to nothing. Thus enormous erosion on hill-sides takes place, damaging the roads below, destroying and choking culverts and side-drains. The extent of subsidence is so great at times that the road goes down by more than a hundred feet. This type of erosion is very common in the Naga Hills and, when it takes place, it is a difficult problem to maintain the traffic.

Soil exposed on hill sides is not only subjected to weathering action, but chemical and physical changes are always taking place. Rain-water plays a very prominent part in changing and destroying the structure of the soil. The injurious effects of the action of water are mainly caused by seepage, subgrade drainage, capillary action of soil-water and its agency in the process of chemical changes. Soil, having a high co-efficient of

shrinkage, contracts during the dry months, giving rise to crevices and fissures, which, in the rains, arrest and absorb water and its destructive action is gradually brought into play. And the soil, rich in sodium or calcium salts, is easily disloged during the rains. This kind of soil is characterised by deposition on top of a superficial layer of sodium or calcium chloride or sulphate.

It is now evident that, if seepage and subgrade drainage can be reduced to a minimum and the surface water drained off quickly, the chances of erosion are less frequent. Thus any erosion on a hill-side is the direct result of some defect in the drainage system. It is the most important and primary problem in a hill road and none-the-less important in a road in plains, to deal with the drainage water. The exposed area, including the hill-slope, above the road, has got to be drained out very carefully by providing adequate catch-water drains and all water taken across the road through culverts and bridges and drained down the slope below the road. The difficulty comes in where there are seepage and subgrade drainage present, which are not un-common in a hill road, and specially in the Naga Hills, their presence is more evident owing to cultivators impounding water on top of hills and on slopes throughout the rainy season, for the purpose of *Pamkhet* cultivation, (*i.e.*, wet cultivation). Presence of shale-layer in the hill itself also helps impounding water within it. When these are not very deep, they can by intercepted by side drains and drained out on the outer side of the road, *i.e.*, towards the slope. Very deep intercepting drains are not only costly but unsafe for traffic. In certain countries, *e g.*, in America they are adopting perforated Armco pipes as deep intercepting side drains for protecting the road foundation against seepage and percolation. These perforated metal pipes, (or concrete pipes), can be laid as deep as necessary for intercepting subsoil water and covered up on the top But this method is very costly and out of question for adoption in our country, as our roads always suffer from paucity of funds even for its ordinary requirements.

Slip and subsidence or erosion and settlement are so very interconnected that one follows the other like a shadow. But at times, settlement of the road surface takes place though apparently no slip is visible. This generally takes place where the road has been crossed over low points of embanked slopes by means of earthfilling or retaining wall, without providing any opening across the road. The hill ranges generally follow a meandering course instead of a straight one and curves are formed by the steep hill slopes either in the direction of the slope or away from it. In the former case there is invariably a depression which serves as natural waterway down the slope and it is a folly to block such a depression as it is not a big channel or as it only comes into action during the flood season. Such natural waterways at the lowest point of curves have been blocked in many places in the Dimapur-Manipur Road. And these spots are the weak links in the whole system and are subject to annual recurrence of subsidences. The damaged road had been restored year after year, without any attempts being made to investigate into the real cause of it and to eradicate it once for all. The writer has successfully tackled some of the bad subsidences in the Dimapur-Manipur Road either by providing an additional opening or by shifting the position of an existing opening to the lowest point; and also by providing intercepting side-drains, so that percolation through the foundation of the road may be stopped.

When we try to go against nature, we have got to pay for it in one way or other. And this is quite true in the case of efficient maintenance of a mountain road. Our aim should be to help nature in draining out quickly, free and impounded water by providing more artificial waterways instead of closing natural ones and thus help subgrade stabilisation. When the natural waterways are closed at the lowest points it often happens that water accummulates behind the shoulder of the road forming a pool which finally cuts across the road or overflows the road, cutting the berm and eroding the slope below the road, or percolates underneath resulting in seepage.

In one portion of the road, there is a big curve in which a natural channel coming down the slope of the two adjacent hills had not been provided with any outlet across the road but water led through side drains and the slope below the road just opposite to this is very steep, the road being protected by a retaining wall. The rush of water through the channel during floods was very big and a lot of debris came down which could not pass through the side drains, as a result of this water overflowed the road cutting and eroding the slope below the road just by the side of the retaining wall and the whole road subsided every year at the same spot. Provision of an opening at this place is very costly on account of the steep hill slope, so the side drain has been deepened, widened and made *pucca* with stone masonry and a basin has been provided above the shoulder of the road. Thus the situation has been met with successfully and the subsidence has been arrested.

Thus action has to be taken in different places suiting circumstances and environments.

Some of the natural waterways in the curves of embanked slopes, which form into streams and ravines, are very deep, having steep gorges on both sides below the road. And their beds and banks (*i.e.*, sides) are subjected to scour at every rush of water during the rains. Thus the bottom of the steep hill-slopes is undermined on both sides of the channel resulting in land-slide due to removal of back pressure. This kind of erosion and settlement have been very successfully tackled by putting in series of boulder sausages encased in strong wire netting across the channel. By this sort of treatment the bed of the channel has been raised very quickly, as all debris, silt etc. are arrested and deposited in between the sausages. Thus additional support or backing is provided at the bottom of the steep slopes. When the channel is not very big and the rush of water not so strong, the boulder sausages are replaced wholly or partly by jungle wood spurs, which are also equally effective. By continuing this operation for several years, the bed of the channel is raised sufficiently till a natural equilibrium is established. In certain cases, it has been found necessary to provide either a boulder sausage encased in wire netting, or a dry stone-masonry retaining wall, or both, along the toe of the steep slope just to provide necessary support or back pressure.

Land-slides that take place in the Naga Hills may be classified under three different types

(1) First, in which the erosion is localised to a portion above the road, and the road itself or the portion down below remaining undisturbed. Such a slip is dealt with by removing the eroded products down below, the road and intercepting all seepage water by side-drain and draining out the effected area

efficiently. Sometimes, it is also essential to provide retaining wall just above the road.

(2) Second, in which the slip takes place by dislodgement of the entire hill side starting from the top of the hill down to the toe of the slope, damaging the road and any structure thereby. In such a case it is necessary to help all eroded products or any dislodged mass to slide down and come to a stable state, by itself. Nature, by her destruction in one place, builds in another, and a state of equilibrium is gradually established. During the process of sliding down of the big masses, the entire surface is subjected to a great upheaval and it is very loose and pervious, so it is necessary to dress and level the area and provide waterways all over, so that all free-water can run down quickly. Drainage water, coming from above the effected area, has got to be led through catch-water drains.

(3) Third, in which the slip is confined to the road itself and the portion down below. This is commonly known as subsidence. In such a case the real cause has got to be investigated and removed. Percolation, in-sufficient waterway or blockage of natural water passage, or removal of pressure down below are generally responsible for such a slip.

Drainage outlets across the road should be numerous and ample and no natural water passage, howsoever tiny, should be closed. Broadly speaking, erosion is due to some defect in drainage system and no protection work is of any avail unless the root cause is removed. Placing the culvert opening in a wrong situation is a common mistake in a hill road. Water is bound to follow the lowest point and the way of least resistence, so it is a folly to obstruct the natural water-course and try to force it to follow a course which nature resents. If we do not go against nature but try to work conjointly with her some of the greatest disasters can be easily averted.

Excavated materials or spoil obtained by widening curves or realigning the road or in clearing slips are genarally thrown down below the road. This has got to be done carefully so that no additional weight may be imposed on the slope and disturb the equilibrium. The spoil can profitably be utilised in filling up natural recesses below hill-side curves or low berms, providing additional width to the road. The filling thus made is liable to erosion during the first rains specially when the soil is pervious. It is a good practice to give a top-layer of earth which is more or less impervious. While cutting hill-sides, seepage and spring water is often met with and such water has got to be intercepted by side drains and led across the road through proper openings. The ideal condition to get rid of slip and subsidence is to have the road and its surroundings perfectly water-tight. But this ideal condition is practically impossible but attempts should be made to retain the security of the road and its surroundings from the destructive action of water by providing adequate water-ways, draining the free and impounded water quickly and reducing percolation under the road foundation as far as practicable.

It is often the cause that water from the discharge through culvert openings, or gullies, erodes the slope below the road due to water soaking in loose soil or through crevices and fissures. In such a case it becomes neces-

sary to lead the water beyond effected area by means of pipe or metal culverts. This is very essential when erosion products from above spread over the road and slope down below and the traffic has got to be maintained over the slip area. It is costly to have pipe or metal culvert and we have improvised half-metal culverts out of the empty barrels obtained from surface painting work. These empty barrels and metal sheets made from them are of immense importance in fighting against erosion in a hill road. The slopes, both above and below the road, have got to be drained properly, including dressing and levelling all fissures and cracks, together with smoothing down of any loose soil before the advent of the rains. Growth of vegetation on the slopes helps stabilization of soil to a certain extent and plants and shrubs with dense fibrous roots, such as *'ckra'* or *'wattle'* and similar bushes or grass or reed may be grown on the slopes. But, too dense a forest impedes the easy run off or flow of water and should not be encouraged.

I am not competent enough to deal with all the problems of a mountain road. Here I have only dealt with some of the problems that we are faced with, in the Naga Hills. And I shall be obliged and thankful if road Engineers come forward with valuable suggestions on this matter.

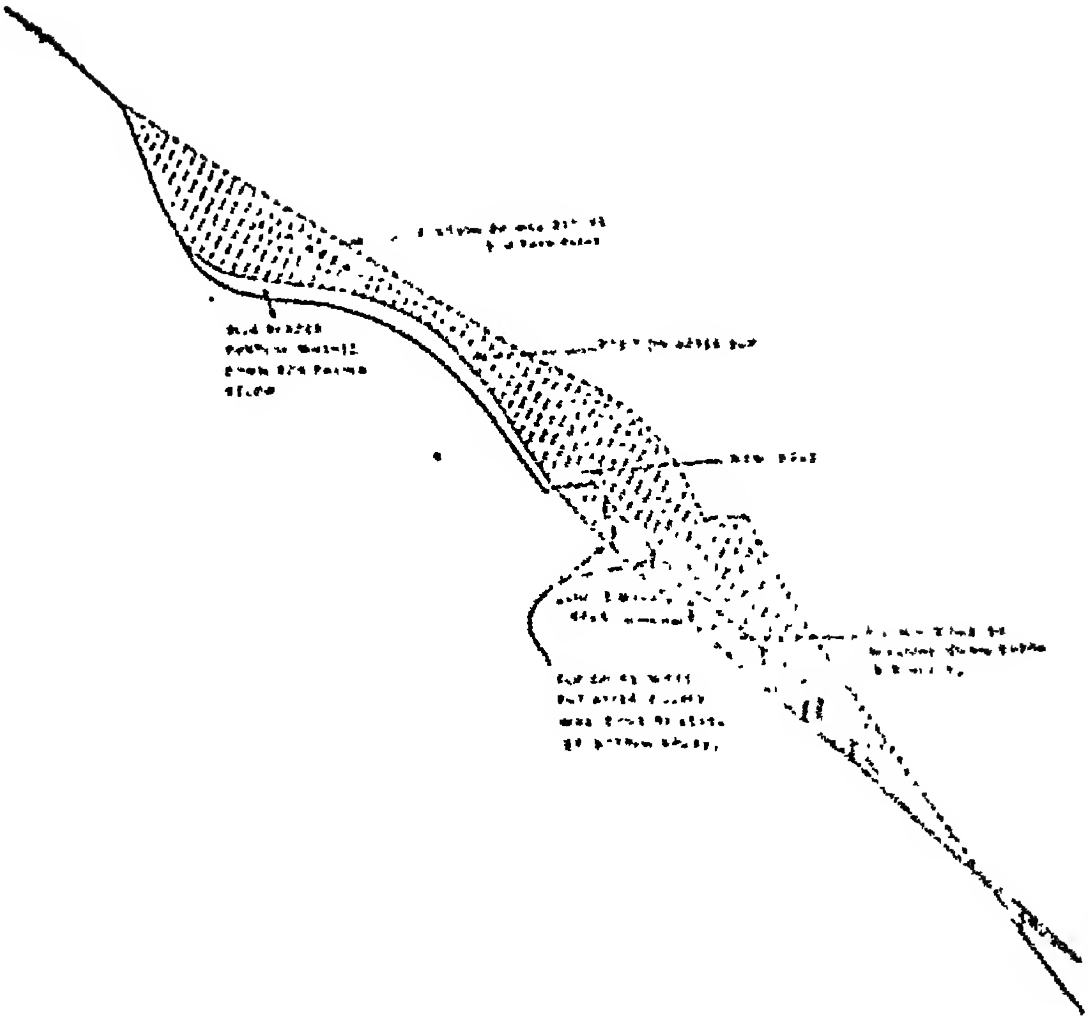
DISCUSSIONS ON PAPER I-39

Mr. D. C. Datta (Assam): In introducing my paper, I beg to say that since my submission of it there have been very big landslides in three different miles of the Dimapur-Manipur Road, dislocating the traffic for several months. In one case the landslide was rather peculiar, forming into a deep and wide depression. The drop at the top of the slide, where it sheared from the parent mountain, was about 50 feet. The hill-side took a very steep slope and it became a difficult problem for opening out a diversion. To fill up the gap meant more than 5 lakhs cubic feet of earthwork and cutting and opening a track on the hill-side was out of the question, owing to the movement of the entire area. The landslide took place in the later part of June when the monsoon was in full swing, and such a huge quantity of earthwork at that time was not possible.

On the top of the hill, there are "*panikhets*" (*i.e.* wet cultivation), and the structure of the soil is shale and earth mixed with boulder, and there were percolation and impounded water which caused the slide. After the slide had taken place, a lot of impounded and subsoil water had to be tapped out. This water and the drainage water were all collected and diverted over the slip, washing down earth, shale and *debris* of boulder. This was done with a view to reduce the steepness of the hill-slope. At the same time, to arrest the solid matter thus washed down from being carried far below, series of jungle wood spurs were put at intervals. By improvising this method, during the months of July and August, when no earthwork could be done, filling was done in gradual slope. Thus nature was harnessed to do the constructive work at one place, while she was doing destruction in another. In this way, it became possible to do all the filling. The filling thus made became very compact and firm, and equilibrium could be established, because of the spurs which provided the necessary back pressure from down below. The road could be made ready and through traffic restored by September 1, in spite of the unfavourable weather conditions. For final filling, of course, about 70,000 cubic feet of earthwork had to be done.

I submit my paper not as a specialist but as a practical worker, as a man on the spot who has to find his way out while working, for getting over a difficult situation, depending on the circumstances and environments, and for this no hard and fast rules can be laid down.

ROUGH SECTION OF A SLIP



Mr. Ali Ahmed (Assam): I am glad that by the presentation of his paper on "Slips and Subsidence on a Hill Road" Mr. Datta has brought forward before the road Engineers a problem with which we have been confronted in Assam for several years. Mr. Datta has endeavoured to study it while he has been in charge of the road and he has put down his observations in his paper. The paper, however, stops short at that. It merely mentions certain ordinary maintenance problems of a hill road and does not go further. I think something more than this is required.

Mr. Datta has made certain statements which, I am afraid, are not very accurate. On page 2 (i) he says:

" The hill ranges generally follow a meandering course instead of a straight one and curves are formed by the steep hill slopes either in the direction of the slope or away from it. In the former case there is invariably a depression which serves as natural waterway down the slope and it is a folly to block such a depression as it is not a big channel or it only comes into action during the flood season. Such natural waterways at the lowest point of curves have been blocked in many places in the Dimapur-Manipur Road. "

In this he is referring to the blocking of water flowing down at the lowest points of curves and he says that the spots where this has been done are weak links in the whole system and are subject to annual recurrences of subsidences. In para 1 on page 3 (i) he says:

" Our aim should be to help nature in draining out quickly free and impounded water by providing more artificial waterways instead of closing natural ones and thus help subgrade stabilisation. "

Evidently, he means that wherever you have got these curves you must provide a waterway. Now a Hill road is never straight. In every furlong there will be curves; you may have a concave or a convex curve. The water courses are generally led through at the concave curves. Where you get a lot of water coming down the side drains, of course you may let it out at any place where the accumulation is too great or where you find that by allowing it across the road you will not wash down the slope downstream and interfere with the stability of the hill side. To provide a waterway at every concave curve would mean tremendous expense on bridges and culverts in building the road initially and very large expense later on in maintenance. So, naturally what you do is to allow the water either to be caught by the catchwater drains or allow it to flow into your side drains and then let it out at suitable intervals into water courses which already exist or by providing special outlets where there are no water channels. The sweeping statement that more artificial waterways should be provided at all curves cannot be accepted entirely.

Then on page 2 (i) he also says:

" And these spots are the weak links in the whole system and are subject to annual recurrence of subsidences. The damaged road had been restored year after year, without any attempts being made to investigate into the real cause of it and to eradicate it once for all. "

This is a very damaging statement and not true. I have been associated with this Dimapur-Manipur Road off and on for over 25 years, and I know its history much more than Mr. Datta does. It has been in

charge of very eminent engineers, and naturally you have all the senior departmental officers going and inspecting it, recording their inspection notes and giving directions. It should be remembered that on a hill road matters do not remain constant. It often happens that if you have a channel at one place, it is all of a sudden blocked and the water turns to another place nearby. In that case, you have to redesign your cross drainage at the point. What Mr. Datta is referring to must be some such example where previously there was no flow of water, and naturally an embankment right across would do. Later on you find that something happens above the road and brings the water down at that place where certain filling has been done. Naturally the water will rush there and it will start percolating, and you must provide an outlet at that place. Things do not remain constant. Again you will find that there are very heavy slips in one particular year, but in subsequent years you will find that there is absolutely no trouble with that part of the road during the rainy season, whereas close by, the hill side starts moving at a place which has been stable for a long time. You cannot say that this problem was not tackled before. Problems have to be tackled as they present themselves.

On page 3 (i), in the second paragraph he himself says:

"The rush of water through the channel during floods was very big and a lot of debris came down which could not pass through the side drains; as a result of this water overflowed the road cutting and eroding the slope below the road just by the side of the retaining wall and the whole road subsided every year at the same spot. Provision of an opening at this place is very costly on account of the steep hill slope; so the side drain has been deepened, widened and made *pucca* with stone masonry and a basin has been provided above the shoulder of the road. Thus the situation has been met with successfully and the subsidence has been arrested."

He has himself not provided any waterway, but he has carried water along side drains and thus relieved the situation.

Then again, on page 5 (i) he says:

"But too dense a forest impedes the easy run off or flow of water and should not be encouraged."

I do not understand it. I hope Mr. Datta will explain it. As far as I know, forest does help greatly in preventing land slips. Large trees act as huge sponges. They retain large quantities of rain water to be gradually evaporated after the rains; they stop soil erosion; they break the force of the rain water. So they help quite a lot in stabilising the hill side. Mr. Datta says that this should not be encouraged. I hope he will explain what he means. In fact, he himself says that plants and shrubs with dense fibrous roots, such as *ekra* or *wattle* and similar bushes or grass or reed may be grown on the slopes. If his idea is that forest will impede the easy run off of water, I should like to know from him whether "ekra" or other shrubs do not, in his opinion, impede the flow of water.

I come to the main problem which, while indroducing his paper, Mr. Datta has brought forward. This road is a hill road. It passes through non-regulated area, the Naga Hills and the Manipur State. In

dealing with these slips we were confronted with several difficulties. In the first place there is the political difficulty. Being a non-regulated area, you have to respect the rights of the local tribes, which are the Nagas. These, people are experts in terrace cultivation. I think they build the finest terraces on hill sides to do their cultivation. They are really marvellous and they have got an eye for levels. If they want to have their fields ponded, they will probably go half a mile to some place where they can get water, and bring it down along the side of the hill without taking any levels, simply judging by their eye, and accurately bring it to the point where it is wanted. Naturally, in a hill, cultivation is very meagre. There is very little land available suitable for cultivation, and the fields which these people have got must be kept up. There is no question of acquisition of land or of stopping the ponding of the fields. Naturally, with a strata which is mostly shale, with fields above and below the road, full of water during the rainy season, and then with the heavy intensity of rains during the monsoon, the whole hill side in places begins to slide and the engineering department is put to the task of keeping up the motor traffic. This is exceedingly difficult. Normally, I think we have to stop traffic and do transhipment for two weeks or a month, but this year has been worse ; as Mr. Datta says, from practically June to September the traffic had to be closed.

The problem was looked into. We tried to alter the alignment When we went to the other side of the hill to consider possibility of taking the road through harder strata, it was found that the dip of the rock was against us. The road would also be much longer and it would mean tremendous cost to build the road. We had no alternative but to keep the road where it was and just to go on as best as we could. The problem, to be properly tackled, would mean the acquisition of large areas above the road and below the road in order to provide efficient drainage, so that water may flow and not be obstructed, have quick-growing forest trees which will take kindly to the shale soil planted, have a trench system with perforated drains, or boulder filled drains below ground, and then have breast walls as well as retaining walls at intervals. This will mean tremendous expense which the Province cannot afford. So, it is not so easy to stop these slips and subsidences on this hill road. We have got other hill roads in the Province. We have got the Gauhati-Shillong road, the Sylhet-Shillong road, the Lohit Valley road, etc. The conditions there are quite good. We keep up the traffic throughout the year without interruption. The case of the Dimapur-Manipur road is a special one, and I do not know if you have got a parallel for it in India. If any road engineers could give us any helpful information, we would indeed be very grateful.

Mr. W. L. Murrell (Chairman): Pesonally I have not had much experience of hill slips or subsidences on hill roads, but I cannot agree with Mr. Ali Ahmed's remark about too many culverts on hill roads increasing maintenance expenditure. On our hill roads I find that, if culverts are not fairly frequent, water from heavy storms accumulates in the side drains, scours out the berms, and damages any waterbound surfaces.

It is good to find young officers writing papers, and it is hoped that the author will not be discouraged by one or two remarks passed during the discussion.

On behalf of the Congress I cordially thank Mr. Datta for his paper.

CORRESPONDENCE ON PAPER I—39

1. Comments of Mr. N. Das Gupta, Calcutta.

I did not intend to speak on Mr. Datta's paper, but in view of a controversial comment made by Mr. Ali Ahmed, I intend to give my views.

Mr. Ali Ahmed considers that large trees help in stabilizing hill roads, but I personally think that it is just the opposite case. One cause of disintegration of hills is due to extension of roots of large tress into the soil and ultimately cracking the hill itself. This phenomenon is very common and everyone who has visited hills containing large tress will share my views.

2 Comments of Mr. M. Mahapatra, Sambalpur.

Slips are a source of trouble in hill roads. In rainy seasons slips become so much that at times the road is blocked to traffic In the ghat portion of Itkivalsa—Jeypore road of Koraput District, boulders of huge sizes upto 10 feet in length often come down to the road surface during rains. No special action was taken for the prevention of slip. After investigation it was discovered that the coolies in course of metal collection disturb the natural bed of the boulders by removing a stone here and a stone there. As soon as the first shower pours down the loose earth in the excavated pits on the slopes high up the hill sinks down and causes the slip. Blocking up of the catchwater drains accelerates the slip

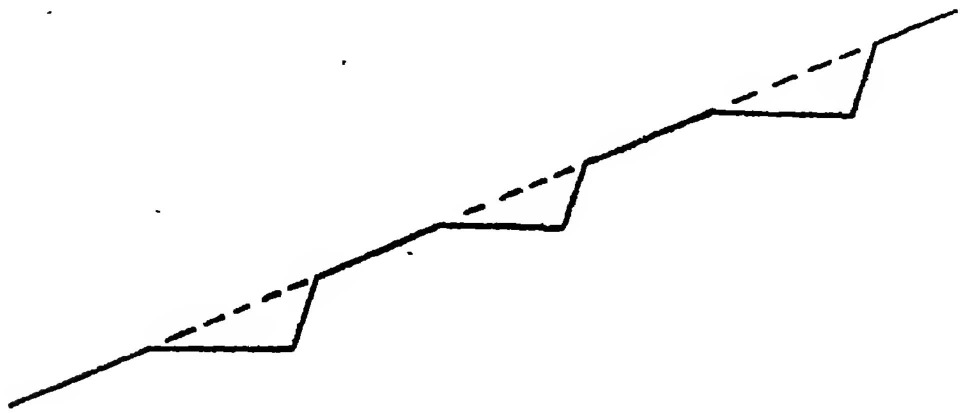
Action taken to minimise the slip was to have constant watch over the course of the catchwater drains and to see that they function properly; and to stop collection of metal or any sort of cutting in the hill slope. By this the slip was much minimised. The slips on the valley side were prevented by rough stone dry pitching.

The sketch case V of the paper showing boulder sausages encased in wire netting adopted for raising the bed of the hill stream is not clear to me so far the foundation is concerned. It appears from the sketch that the foundation of the sausage is parallel to the bed slope of the stream. The author will please say whether any sign of slip was observed in the boulder sausages

3. Comments of Nawab Ahsan Yar Jung Bahadur, Hyderabad-Deccan.

I entirely agree with the Author that in case of hill roads a policy of economical disposal of storm water should never be followed. It results in the end after all to serious troubles and heavy ultimate cost. In fact it is really false economy to cut down cross drainage outlets. The Author is perfectly right in the views expressed by him after his personal experience. All Hill Roads have to be very carefully designed after extensive reconnoitering the country and trying various alternative alignments. Specially when negotiating a high hill the alignment should never be taken on the slope one on top of the other (*vide* sketch below) by merely providing hair-pin curves and gaining length so as to be within the ruling gradient. Such alignments are highly

dangerous and very difficult to maintain as a slip or wash-away on one of the top lines simply cuts away the other portions below.



It is always advisable in such cases to contour round and if possible tunnel through. No doubt tunnels are expensive to construct, but it is, found that if they are pierced in rocky strata, as is generally the case, the alignment is not liable to be damaged so frequently. This is our experience in the Ghat Sections on the Railways.

4. Reply of Mr. D. C. Datta (Author) to the comments.

Mr. Ali Ahmed, has accused me for brevity and for dealing with ordinary maintenance problems. I have simply tried to put together, in my paper, certain results of observations under the existing conditions without going into the details of selection of an alignment in a mountain road. And it is not possible within the compass of such a paper to deal with all the problems, nor do I consider myself competent enough to speak authoritatively on the subject. I am dealing with an existing road; so all its problems are very closely connected with the maintenance of the road. I have dealt with the fundamental principles necessary for a new construction, or realignment or improvement of an existing one.

As to the statement on page 2 (i) of my paper, quoted by Mr. Ahmed, I can only say that he has later on admitted that all the lowest points of curves have not been provided by an outlet across the road in the Dimapur-Manipur Road. He is inclined to be very conservative in providing artificial water-ways. But the basis of stability of a mountain road, depends on quick disposal of storm water and this is not effected unless there are a sufficient number of drainage outlets from the road. For a new construction, I would advocate either a bridge or a culvert at every natural water passage, but in an existing road the conditions, however defective it might be, cannot be altered all at once, as the activities are limited by various factors. Provision of drainages outlets, even at every concave curve, at the time of initial construction, means an additional expense no doubt, but it is relatively small compared with the cost of construction or maintenance of the road. I disagree with Mr. Ahmed in his views that the maintenance expenses on bridges and culverts are high. Bridges and culverts, properly designed and located, require very little in the way of

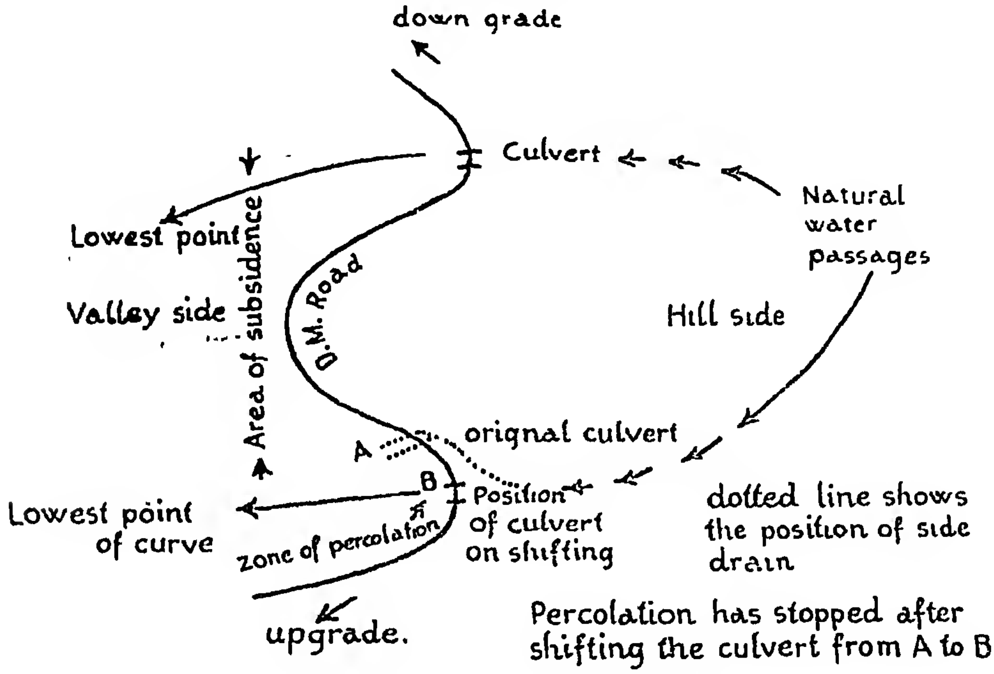
maintenance. The statement that more artificial water-ways are needed in the Dimapur-Manipur Road, is justified by the fact that a lot of money is spent every year, in making good the damages done to the road by storm water by cutting here and there. The number of outlets from the road should not only be numerous but the openings should also be adequate to accommodate heavy rush of water and avoid choking by debris. Considerable damage is done to the Dimapur-Manipur Road, every year, by choking of bridges and culverts.

I am really very sorry that Mr. Ahmed has classified a certain statement of mine as very damaging. It is far from it, I simply stated the circumstances and facts as they appeared, without the least pretension of throwing any aspersion to the ability of any past Engineers. As the subsidences are there and the under ground percolation still persisting and some of them could be improved, as stated in my paper, I can only say that the circumstances led me to that conclusion. Mr. Ahmed claims that matters do not remain constant in a hill road. It is true no doubt, but the changes are not such as to alter the whole configuration unless there is a geological upheaval or denudation. Our outlook is changing more rapidly, and 25 years back, when the road was hardly used during the rains, the conditions that were not considered so injurious are of great consequences now-a-days. It is, I should say, an established fact that provisions of insufficient waterways in the Dimapur-Manipur Road is the main cause of damages and changes brought upon this Road annually, and plays a great part in adding to the maintenance cost.

As to the next point, regarding my remarks in para 2 on page 3 (i) quoted by Mr. Ahmed, I beg to say that the Engineer-in-charge of an existing road, has not only got to be guided by the existing conditions but also by the funds available. It is a known fact that what is possible to do in a new construction, may not be permissible in an existing road. Each problem has got to be solved most economically and on its own merits. There are many instances, in the Dimapur-Manipur Road of the leading of drainage water through side-drains and letting out across the road away from the lowest point of the curve. But all have not proved successful and in many cases water percolates underneath the road. Whether a channel coming down the hill slope, is to be drained through a side-drain for a certain length and then led through a cross drain, or through a cross drain straightaway, depends entirely on local conditions. What is wanted is a compromise of the prevailing circumstances so as to ensure the best and economical results.

I can cite a very interesting example here of a regular stream through the bank for not providing an outlet at the lowest point of the curve. In a concave curve in the 24th mile of Dimapur-Manipur Road, drainge water from the hill slope was directed to pass by the side drain and led across the road through a culvert situated at a point about 60 feet down grade from the lowest point of the embanked slope. High storm water used to pass by the route meant for it but normal drainage water percolated underneath forming into an underground stream. It is not known for how long this state of affairs existed. One day the writer's attention was drawn by the rumbling sound of flowing stream at the lowest point of the curve though there was no outlet at the point and no water was flowing through the side drain or the culvert further down. On investigation, it was found out that water was coming out in a regular stream

down the road side slope at a depth of 20 feet or so below the road crest. This under-ground drainage caused subsidence to the portion just beyond this point on the downgrade side. On shifting the culvert to the lowest point with a bigger opening, no subsidence or percolation was noticed during the last rains. There being no direct outlet at the spot, the road, too, used to get blocked by debris and boulders coming down the hill. This blocking also did not take place in the last rains. The location of the culvert with a bigger opening at the lowest point during the time of initial construction would not have cost much and probably the subsidence might not have taken place.



ROUGH SKETCH OF THE ROAD

I disagree with Mr. Ahmed in his remarks about large trees helping stabilisation. Slopes which are properly drained require protection against excessive weathering and such protection is helped by light growth of vegetation. Vegetation is wanted just to provide a sort of permanent cover so that free water may not percolate underneath but at the same time it should not be so dense as to offer resistance to water flowing down. Any accummulation of water due to obstruction may result in underground percolation. Large trees with huge roots will not provide what is wanted but on the contrary, if there be any percolation and soluble salts present in the soil, the big trees will exert additional weight and thin layers will slide down. This phenomenon is not uncommon in the Naga Hills. Some of the curves in the hill range do not get sun at all and any dense forest in those places will keep the hill side always wet giving place to percolation in the rains. The little moisture wanted for weathering purposes, is best maintained by grass, shrubs and bushes of light nature. Growth of vegetation should be just enough to meet our requirements and nothing more. Too much of any thing is just as bad as nothing. Big trees and dense forest, in other words, afforestation, attract clouds causing more rainfall in the locality, this is why dense forest should not be encouraged.

As to recurrence of big slips I would like to say that we have not yet been able to tackle them successfully. I do not consider it quite impossible but we have not got the resources at our control. Protection from erosion is best provided at the time of initial construction. By the extended use of retaining walls made from local stone or of concrete, erosion can be greatly minimised but it is all a question of money. Tunnelling reduces erosion but it is all the more costlier.

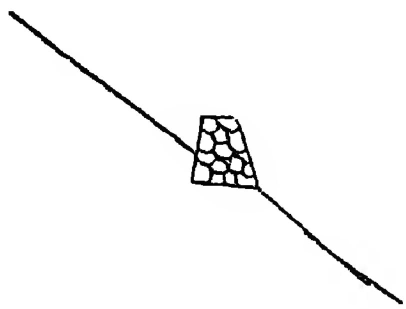
Mr. N. Das Gupta has spoken on the unsuitability of plantation of big trees and I fully agree with him in his view that big trees by extending their roots all over the place help water in finding its way through crevices. Slips of the nature as enumerated by the speaker are often met with in the Dimapur—Manipur Road during the rains.

Slips due to disturbance of natural bed of the boulders as stated by Mr. M. Mahapatra are not so serious and can be tackled successfully. The difficulties arise when the structure of the hill is made of shale or soil with soluble salts and the erosion extends over a large area. Not only blocking up of the catch water drains but also natural water passages, is the main cause of slips.

It is quite true, as has been suggested, that by keeping constant watch over the drainage system, slips can be minimised. But I would like to go a step further and say that the free and the impounded water, if not properly dealt with, are the main causes of slips. Where these can be controlled, other factors do not count so much. Stone breast wall, stone pitching or boulder sausage all help in reducing the slip on the valley side and when the slip is confined to a small area it can be totally arrested provided there is no percolation. But big slips extending over a large area need more elaborate arrangements and costly measures which we often cannot afford.

Regarding the sketch, case V *vide* page 6 (*i*), I beg to say that owing to small size and printing mistake it has not been very clear. The foundation of the sausage is not quite parallel to the bed but slightly inclined and embedded on the up stream side as shown here.

This is necessary for stable foundation. The inclination may be increased according to steepness of the slope of the bed. No sign of slip has been noticed but in two cases the sausages were badly damaged by water cutting from the sides. This was due to the bridge openings being choked completely by boulders, etc and water rushing over the road and cutting from the sides.



I am thankful to Nawab Ahsan Yar Jung Bahadur for giving his full support to my views on liberal disposal of storm water in hill roads. Any economy in cutting down drainage outlets results in serious consequences in later years. I know of many instances where omission of culverts and reduction in bridge openings resulted in serious breaches

in subsequent years. It is a false economy and should be guarded against. And it can be said with authority that cutting down of waterways in any road is a source of great drain on the future upkeep cost of the road. I fully agree with Nawab Sahib in his views on the selection of alignment. Proper selection of alignment and liberal provision of waterways for quick disposal of storm water are assets to a hill road.

Tunnelling on a steep hill slope may reduce slips but it, being very costly, cannot be adopted for ordinary roads whereas on the Railways such an extra initial cost is an investment and it pays in the long run.

PAPER F—39

Mr. S. Bashiram (Chairman) :—I would call upon Mr. S. R. Mehra ,to introduce his paper.

The following paper was then taken as read :—

PAPER No. F—39

STABILIZATION OF THE UNMETALLED BERMS OF METALLED ROADS.

By

S. R. Mehra, Assoc. M. Inst. C. E.

Officer on Special Duty, Communications Board, Punjab.

1. **Introduction.**—In rural areas the usual range of widths of metalling of the metalled roads in our country, is 9 feet to 12 feet only, the rest of the formation consisting of a *kachha* berm on each side. Although most of the metalled roads nowadays are surface treated, and consequently dust free over the metalled width, the *kachha* berm has to be necessarily used, when crossing or overtaking a vehicle.

In these days of fast moving traffic, the danger to human life and property involved in having to go on to the *kachha* berm while travelling at high speed, is only too well known to the motorists. Besides the element of danger involved, it is most unpleasant and unhealthy to travel on these roads, both in the dry and in the wet weather.

In the dry weather, the clouds of dust set up when crossing or overtaking are dangerous, as they shut off front view. There are many cases on record, when a motor car going behind a motor lorry, has struck into a bullock cart going in front of the lorry, after the lorry has overtaken the bullock cart and hidden it from the sight of the motor car driver by leaving a dust screen between it and the car. There is also danger of skidding in the loose dry earth. And dust in those liberal quantities, even to us who are so familiar with it, is bad for the eyes and lungs. It would not be too much to say that the dustiness of our roads contributes very greatly to the spread of disease and consequent misery, in this country.

In the wet weather, the slipperiness caused in most places, on the *kachha* berms results in many accidents from skidding etc., besides the mud splutter and nervous shock, which comes naturally every time a vehicle is crossed.

It is only too evident that the metalled roads, as at present, are not suitable for the speeds which are prevalent these days.

The obvious remedy is to widen the metalling on the roads, but to do that at any reasonable speed, requires money in amounts which the country can not immediately produce. In addition, the widening of metalling will necessarily fast increase the ordinary maintenance estimates, which, again, we can ill afford at present. The rate at which the widening of metalling is proceeding at present, is far from satisfactory, and due to the rapidly increasing motor traffic; the problem is getting keener from year to year.

The solution of this problem, next best to widening of the metalling, is the improvement of the *kachha* berms. This aspect of the question has remained entirely in the back ground for want of a cheap, satisfactory solution.

But, thanks to the recent developments in soil science as applied to roads, it is no longer an impossible task to tackle the thousands of miles of *kachha* berms, which demand the urgent attention of the various road authorities.

The use of insoluble binders in the stabilization of soils, according to the methods standardised so far, is unfortunately rather expensive. It has a further handicap in the fact, that the soil thus stabilized has no recuperative value and must necessarily be prevented from breaking up by additional surface treatment. It appears, therefore, that further research must be carried out in this direction so as to bring the treatment within economic reach.

With a view to find a cheap solution of this problem, a soil survey of some of the important metalled roads in the Punjab was undertaken, and the condition of the berms in the various miles was studied along with the availability of other necessary materials in the near vicinity.

The scheme of stabilization of berms evolved as a result of the survey is as follows.

The soil mixture on the berms in each mile should first be classified and the deficient ingredients therein determined. Soil mixtures, over-rich in those very ingredients should then be looked for near the vicinity and collected in required quantities at site, by ordinary maintenance gangs. The admixture should be added to the defective berm soil, under suitable weather conditions, and after giving it an initial compaction, it should be allowed to compact finally under traffic by artificially creating suitable moisture conditions for some time. Cheap coarse material should be added to take up surface abrasion. In making up the worn out berm later, the same mixture should be used and compacted in the same way.

The first essential and the one that presented the greatest difficulty, was a handy method for the classification of soils. It is possible by a combination of field observations and laboratory routine tests, to classify a soil fairly accurately and to propose a suitable treatment for overcoming its shortcomings if any. But, for an extensive work of this nature, which is proposed to be done mainly out of the meagre savings of the ordinary maintenance estimates and the success of which depends entirely on the co-operation and goodwill of the local officers, it was felt that the method of classification of soils should be entirely a field method, easily usable by local officers.

The best field method for the classification of soils, put forward so far, is the judging of the clay content of a soil, by specially trained men, having a lot of experience of the work.

Even if it was found possible to train all the mates and road inspectors, etc. to judge by the sight and feel the quantity of that tricky substance called clay in a soil, the classification would be far from satisfactory.

To begin with, different investigators define clay differently.

Besides, it is not the clay content iself in a soil that matters, but the effect of the clay content on the adhesive strength of the soil and on its behaviour under varying moisture conditions.

A soil having a large percentage of clay may actually have less cohesion than another having a small percentage of clay. This queer phenomenon is due to the fact that clay may exist in a soil either in a completely dispersed

state, or in varying degrees of flocculation. The cohesion in a soil mixture is due to the coating of coarser cohesionless particles of soil by adhesive clay. Upto the optimum quantity, if a certain quantity of clay exists in a completely dispersed state in a soil mixture, it coats the maximum possible number of particles and consequently produces maximum cohesion for that quantity of clay. If on the other hand, the same quantity of clay exists in a similar soil mixture in a flocculated state, the number of coarser particles that it coats, as also the consequent cohesion, will decrease as the degree of flocculation of the clay increases. So, it is the degree of flocculation of the clay content of a soil in combination with the total clay, that will determine soil behaviour and not the total clay content alone. To determine the degree of flocculation in the field is not possible. Further, the behaviour of the soil will depend on its base exchange capacity and a complexity of other factors, such as particle grading, local weather and traffic conditions etc., etc. The determination of the clay content of a soil would not, therefore, help in even approximately classifying a soil.

The system of classification, evolved as a result of the soil survey referred to above and as outlined in the body of this paper, is based on the actual behaviour of soil mixtures under local traffic conditions, and the varying conditions of weather. This automatically obviates altogether, the very tricky question of the clay content of a soil, on which previous attempts at a field method for the classification of soils have been based.

The simplicity of this method lies in the fact that all the information required, *viz.* the behaviour of soil under traffic during different seasons, is readily available at site, from old road inspectors, mates and coolies working in the lengths concerned, who are well acquainted with such behaviour. This information can be checked up from time to time by personal inspections of the engineer-in-charge during the course of routine touring.

It will be apparent from a perusal of the scheme, that occasional watering is an important feature of the proposed process of stabilization, specially when coarse material is not obtainable. Canal water can be gravitated along the roadside in more than 75 percent of the metalled miles of roads in the Punjab. It is presumed that water is cheaply available along roadside in a major portion of the metalled miles in other provinces and states also. It is to such areas only where water is readily and cheaply available along the road, that this scheme applies. For the remaining milage, a more suitable method of stabilization will have to be found. Perhaps the use of molasses, tars and bitumens will offer a solution in due course. Work is being pursued already in this direction at the Punjab Irrigation Research Institute.

It is not claimed at all, that the stabilization of berms by the method outlined, will give us dustless roads. But dust and mud in dangerous quantities will certainly disappear, if the berm is judiciously maintained after stabilization. And what is more important, the traffic will be able to use the berm with confidence, each vehicle driver putting one wheel on the berm ungrudgingly while crossing or overtaking, which is not the case at present, and which is consequently one of the important causes of accidents.

It is hoped that after the berms thus stabilized have remained under traffic for a number of years, the widening of metalling will be a matter of surface treating the necessary width after perhaps forcing a very thin skin of stone metal into the stabilized berm.

It is suggested that the maximum width of berm to be thus stabilized should be kept at 5 feet on each side, as, firstly, it is felt that this much usable width (19 to 22 feet) will satisfy the requirements of traffic for many years to come, and, secondly, this is the maximum berm width which can be effectively compacted under traffic.

It is needless to mention that the success of a scheme of this nature depends mostly on the personal interest of the local officers. But, as the poor condition of his unmetalled berms is an eye sore to every road engineer, it could be presumed that such interest will be willingly exhibited.

It can be safely hoped that in the course of not many years, the help of proper soil laboratories will be available to every road engineer in our country for getting his soils analysed. If in the mean time the average road engineer has been handling soils frequently and thus understands their field behaviour fairly well, he will be in a better position to make intelligent use of the laboratory results, than if he has never before had intimate contact with soils. If the scheme outlined in this paper, is given effect to, it will certainly achieve the above result.

Stabilization work according to this scheme, has been started on several roads in the Punjab, and it is hoped that the result of the effort will be reported at the time of the Congress.

2. Preliminary Work.—A careful study of the unmetalled berms of metalled roads in the Punjab and their surroundings comprising a length over 600 miles has revealed the following facts:

(*a*) The dangerous condition of the berms, owing to dustiness in the dry weather and slipperiness in the wet weather, is due mainly to the loose *'pushta'* work on the berms.

(*b*) The earth for *'pushta'* work is selected haphazardly and the gangs naturally have a tendency to use the softest soil available.

(*c*) Even in places where water is available at site, the *'pushta'* is never watered and rolled, with the result that it is quickly scattered about by traffic. Nor is this water used to preserve the berms.

(*d*) The cross fall of the berms, in most cases, is too flat to drain the water quickly. In many cases the berms actually slope inwards ! This results in the rain water standing on the berm against the metalled edge for long periods. The soil gets soft and the traffic forms dangerous pot-holes.

(*e*) Deposits of good fat clay, are available almost all along the roads within a distance of well under a couple of miles.

(*f*) Along many miles, there is plenty of stray metal and *bajri* lying within road-land.

(*g*) In many miles, the berms have, in the course of ordinary maintenance, assimilated a happy mixture of sand, silt and clay, with stray grit or kankar from the metalled portion, which mixture has from time to time been compacted by traffic, under suitable moisture conditions to an extremely high degree.

The condition of the portions as at (g) above, remains very satisfactory during all kinds of weather and the wear is very small indeed, being of the order of about $^3/_1$ inch per year.

3. **Theory of Stabilization.**—Such a mixture of soil would ordinarily be called a stable mixture, which is nothing more or less than a product of the correct proportions of sand, silt and clay, for the local climatic conditions, compacted at the requisite moisture content. The granular material (grit or kankar in (g) above) provides abrasive resistance to the surface, besides giving a general structural stability to the soil mass.

The functions of the three ingredients of soil, *viz.* sand, silt and clay are that sand provides internal friction, still by providing necessary grading acts as a filler for the pore space in the sand particles and clay acts as a binder, due to its cohesiveness.

In very wet conditions of weather, it is the internal friction provided by the sand fraction, which gives stability to the soil, because clay softens down and actually acts as a lubricant when very wet, whereas in very dry conditions, the cohesiveness of the clay content plays a prominent part in soil stability.

It is logical to assume, therefore, that if a soil behaves badly in the wet, it needs more sand, whereas if it behaves badly in the dry, it needs more clay, to give it universal stability by removing its respective shortcomings.

A certain amount of soil has from time to time to be necessarily put on the berms, as an item of ordinary maintenance. It should, therefore, be quite possible, as a matter of course, to gradually improve the quality of the soil on the berms, by so selecting the newly added soil, that it will supply the deficient ingredients of the existing soil mixture on the berms.

4. **Classification and Treatment of Soils** :—For purposes of a practically workable scheme of improvement of berms, the soils on the berms may be broadly classified into the following five classes, as the behaviour of each kind of soil under traffic in varying weather conditions must fall approximately within one or the other of these.

Class A.—Soils which are very firm and compact and which do not rut appreciably either in the dry or in the wet weather.

These are stable soils, and the only action of traffic on these is surface abrasion. They can be further improved to resist the abrasive action of vehicular traffic, by incorporating coarse material into them.

The incorporation of coarse material will not only improve the wearing quality of the soil under varying weather conditions, but also increase considerably its bearing capacity.

In the presence of moisture, traffic action continually drives the granular material into the soil and stabilizes the top layers of the sub-grade. Traffic loads are transmitted through the help of the granular material without being widely distributed and gradually increase the density, and consequently the supporting value, of the sub-grade soil and may also reduce its ability to take up moisture.

Class B.—Soils that rut quickly in the dry weather but improve considerably in the wet weather.

These soils have a predominance of sand and they lack in binder clay. To improve such soils, the first essential is to incorporate a sufficient quantity of binder clay into them.

As stated before, it will generally be found that clay deposits are available well within a distance of a couple of miles of the site where clay is needed. The quantity required per mile will be so small that a lead of as much as a couple of miles will not make the treatment too expensive. Taking the extreme case, the cost of importing clay from a distance of two miles for stabilizing a 4½- inch crust 5 feet wide on each side of the metalled width, will be about Rs. 100/-. An experienced mate will be able to find a clay deposit easily on questioning local residents.

As regards the percentage of such a clayey soil to be mixed with the sandy soil, it will depend among other things on the quantity of binder clay present in the clayey soil and the state in which it exists, *i.e.*, flocculated or dispersed. But, for a first approximation, as a rough guide, about 20 percent of the stuff popularly called *"chikni matti"*, added to the sandy soil, should do the trick

If by actual experience it is found that more is required, which will seldom be the case, it can be added later on, keeping in mind that too much clay will give a lot of trouble in the wet weather.

If, however, the soil consists entirely of sand and there is no fine silt present to act as a filler, it will be found that a very large quantity of binder clay will be needed to give it the required stability in the dry weather, with the natural result that this large quantity of clay will cause the mixture to soften easily in the wet weather.

Before, therefore, adding more than 20 percent clayey soil to sand, it should be tried whether the addition of about 15 percent of water-course bed silt to a mixture of 20 percent of clayey soil with the sandy soil, does not give it sufficient stability In most soils, this will not be necessary, as generally a sandy soil contains that much of silt. In addition, there will be some silt in the 20 percent clayey soil added.

The silt content in a sandy soil, can be easily determined by sieving it through a No 200 sieve. The fraction passing through will be silt.

If to the soil thus stabilized, granular material is incorporated as mentioned before, it should further improve the soil in its wearing quality and its bearing capacity.

Class C. Soils that behave very well in the dry weather but rut badly in the wet weather.

These soils have a predominance of clay and can be improved by the addition of sand. Coarse material should naturally improve them further. This can best be done during the rains when the sand and coarse material should be spread on the wet clayey soil and allowed to work themselves into the soft clay, under the action of traffic.

It is advisable to spread a thin layer at a time, in order to ensure thorough mixing. Before spreading a new layer, the surface should be roughly dressed.

Sand and coarse material should be added in equal quantities by volume, till no more will go into the clayey soil.

The quantities of sand and coarse material required will depend naturally on the depth to which the clayey soil softens under the prevalent rain and load conditions.

Class D. Soils that rut badly both in the dry and in the wet weather.

These soils consist mainly of cohesionless silts and require the addition of clay binder and sand both to stabilize them.

The quantities of sand and *"chikni matti"* that will generally be sufficient is 40 percent and 20 percent respectively.

In view of the large quantities of admixtures required in this case and the further expenditure involved in mixing, it would be worth considering whether a good sandy loam is available within economic distance so as to replace the silty soil entirely.

The advantages of the addition of coarse material if easily available, holds good in this case also.

Class E. Soils that get loose and fluffy during winter (commonly called *"Phulna Kallar"*).

These soils contain an excess of sodium sulphate and the fluffiness results from the frequent volume change in alternate hydration and dehydration of the salt, due to changes in humidity and temperature between the nights and days in winter.

This phenomenon has been studied by Dr Puri in the soil section of the Punjab Irrigation Research Institute Laboratory in connection with road research.

The salt rises from below with capillary moisture and a sure way of cutting off the supply of fresh salt from underneath appears to be to interpose a layer of coarse sand which has the property of destroying the capillary force.

If therefore, the soil is removed to a depth of about 9 inches and a 3-inch layer of good coarse pit sand put over the bed thus exposed, and covered with about 6 inches of good salt-free imported soil, no further trouble may be expected from sodium sulphate. The sand should be well compacted while moist. The sand layer must also be confined at the outer edges to prevent lateral flow.

It is obvious that the top 6 inches of soil should be compacted as much as possible, in the presence of moisture, so that it does never disintegrate so much as to allow the traffic to sink down to and disturb the sand layer.

In cases like these, it would be particularly advisable to add coarse material to the top layer.

It is no use trying to stabilize such soils, without using an insular layer of sand between the top crust and the salt-impregnated soil.

5. **Materials.**—*Clay.* It is repeated once again that if a serious effort is made to find good clay, it will be generally available within reasonable distance. Old village ponds are a useful source of supply of clay.

The field tests for a good clay are,

(*i*) When rubbed well between the fingers in a moist state, it leaves them very greasy.

(*ii*) It is very soft when wet.

(*iii*) A dry clod of clay is so hard that it is difficult to break it with the hands.

(*iv*) Big shrinkage cracks appear on the dry surface of a fat clay deposit.

(*v*) A clay that is liked by pottery makers is very good for road purposes.

It is necessary that clay, as an admixture, should be added in a finely powdered form to powdered soil and that both the clay and the soil should be dry. The cheapest way of powdering is to spread the dry clods on the tarred portion of the road and to run a roller over them ; even a one-ton hand roller will serve the purpose in most cases.

It will be found most convenient to dig out the clay from its deposits in the wet weather, when it is soft and to leave it to dry in the shape of small clods. To dig out a good clay when it is dry is an extremely hard and very expensive job. If it is required to dig out clay in the dry weather, the area should be ponded with water for a couple of days, to soften the clay.

Sand. Coarse pit sand, if available, or canal bed sand should be used. When sand is used as an insular layer for arresting the movement of salts, it must be very coarse. For use in stabilization, the sand obtained from canal beds of 10 feet bed width or more will be found quite suitable.

The screenings from the grit used in tarring *i. e.*, those passing the ¼-inch screen are very useful for stabilization and should always be incorporated into the berms, in whatever small quantities they can be found. At present they are allowed to go to waste.

Coarse material. Anything fairly hard and coarse, that is cheaply available will help to improve the soil. Near big towns, large quantities of slag and cinders are available at a very small cost. Cinders are also available at almost all railway stations and factories etc. Well burnt broken bricks and broken pottery could be collected or bought at many abandoned kilns near the road Kankar or gravel is available near the road in several localities.

Besides this, there is a lot of stray metal and grit to be found along many miles, which could be easily scraped, along with the earth, with spades, broken to size and the whole thing mixed into the soil on the berm.

In many miles, which were kankar miles before, small deposits of crushed kankar rejected from the road when scarifying the old surface, are hidden under a thin cover of earth. The old gang coolies seem to know about these deposits, and will easily find them when they are asked to do so.

The coarse material should be graded from 3/4-inch downwards The following figures of grading are given as a general rough guide :—

	Percentege by weight.
Retained on the 1-inch screen.	0
Passing 1-inch screen but retained on 3/4-inch screen	10
Passing 3/4-inch screen but retained on 1/4-inch screen.	50
Passing 1/4-inch screen but retained on a 10 mesh sieve	30
Passing through 10 mesh sieve.	10

The cheapest way of incorporating the granular material would be to spread it on the surface in a very thin layer, during the rains, when the soil is comparatively soft, and to let the traffic work it in. It may be necessary to put empty coaltar drums down the centre of the road, so as to force the traffic over the area thus treated. After the first layer of coarse material has disappeared into the soil, a little more can be spread out as before and the process continued at convenience, till no more coarse material will go in, showing that the crust is well stabilized. In this state, the soil crust will have about 33 percent of coarse material by volume. If the soil is required to be artificially softened for this purpose, it can be done by ponding water over it.

If added to loose dry soil, the quantity of granular material should be about 40 percent of the total crust.

6. **Compaction of Soils** :—It appears superfluous to dwell on the point that if we go to the expense of putting fresh soil on the berm, it must not be left as a dry powder just to be blown off by traffic. To prevent this, it must be moistened and rolled.

In the case of soils, if rolling is done with an ordinary roller the amount of compaction that the soil receives, falls rapidly with the depth from the surface. So that, below a couple of inches from the surface, the amount of compaction received by the soil is very small indeed. This state of affairs results in a very rapid wearing of the surface, and in the breaking up of the crust due to weak foundation.

To prevent this, it is advisable to use a special kind of roller, called the sheeps-foot roller. This roller by virtue of its protruding feet, has a hammering effect on the soil, and compacts it uniformly through its depth from the bottom upwards.

To begin with, the feet sink right down into the soil and gradually sink less and less, as the rolling proceeds, till at last, when the soil is thoroughly compacted, the feet travel almost at the surface, which is then finished off with an ordinary roller, after dressing. The position of the roller should be shifted slightly at the end of each lap, so that the feet are enabled to press uniformly all over the surface.

The use of a Sheeps-foot roller is recommended only when the depth of loose soil to be compacted is over 3 inches.

A diagram of the roller and photographs of a roller at work are given in figures 1 to 4, pages 13 (f) to 15 (f). It can easily be made locally at a cost of well under Rs. 200/-. The roller may be pulled by a pair of bullocks, if available.

The amount of moisture present in the soil when the compaction is done, is related to the maximum compaction that can be produced in it. The dry weight of soil per unit volume of compacted soil, is a measure of the amount of compaction produced in the soil. This dry weight increases rapidly with the moisture content upto a certain limit and then falls, as rapidly again, on further increase of moisture. The moisture at which the dry weight of soil per unit volume is maximum is called the "optimum moisture" for the particular soil and can be determined in the laboratory.

The curve in fig. 5, page 15 (f) explains the phenomenon. To determine the exact "Optimum Moisture" for a soil mixture would naturally require time

and equipment, but a very fair approximation is obtained in practice, when the condition of the soil is not wet but sufficiently moist to allow of its being easily pressed into a ball in the hand.

A practical way of roughly obtaining Optimum Moisture in a soil mixture would be to give it a thick sprinkling of water towards the evening and to let it soak through the depth of the mixture overnight. In the morning, as soon as the soil mixture looks moist but not wet, and can be easily pressed into a ball in the hand without getting sloppy, the rolling can be started. In case too much water has been used, a few hours' evaporation will bring it to the required consistency.

The quantity of water required to properly moisten a soil may be roughly determined beforehand on a small measured quantity of the soil. The quantity to be actually sprinkled should be slightly increased to allow for evaporation etc.

The soils to which coarse aggregate has been added in appreciable quantities do not require to be rolled with a Sheeps-foot roller. An ordinary flat roller will compact them sufficiently to start with, further compaction being done by traffic under suitable moisture conditions.

When the lengths to be treated are small and consequently do not justify the use of a Sheeps-foot roller, the special rammers, as per fig. 6, page 16 (f) may be used. These are made from ordinary square iron rammers.

7. The Importance of Moisture in Soils.—Moisture plays a very important role in the maintenance of soil berms, and, if present in reasonable quantities, it not only increases the wear-resisting qualities of the soil, besides allaying dust, but also helps its compaction under traffic. In those areas, therefore, where canal water can be gravitated along the roadside, the question of watering the berms, whenever opportunity arises, should be impressed upon the road mates. Watering can be done easily by standing in the roadside drain and splashing water on to the berm with the ordinary mortar pan or something similar.

Only one berm should be sprinkled at a time and closed to traffic by putting tiny branches all over. It should be reopened to traffic when the moisture has had time to soak into the soil and when the surface is moist but not wet. The traffic will then consolidate the loose top soil.

Watering berms will more than pay for itself by reducing maintenance costs. Watering applies equally where granular material has been added.

The canal water rate for sprinkling is only about 25 percent of the rate for flooding.

8. General.—*Slope of Berms.* In order to reduce damage to the berms, as a result of the softening of soil by rain-water, and to prevent excessive scour at the same time, an outward slope of 1 in 40 is considered suitable on a stable soil. It is needless to say that arrangements must be provided all along the roads, for drainage of rain-water. This important point seems to receive very little attention at the moment, the natural consequence being, the destruction of berms in many reaches.

At places, however, where it is intended to soften the soil for incorporation of coarse material or sand, it would be just as well to leave the berm sloping inwards till the process is completed.

In order to accelerate the stabilization of berms as much as possible, it would be a good idea to stabilize only five feet wide on each side, to begin with. The rest of the width of berm could be sloped down to the first line of trees where levels permit and grass encouraged to grow on it wherever water is available. The continuous slope will make the road look much safer by doing away with the abrupt drop we have at the edge of the berm at present. The grass will not only reduce dust but also protect the unstabilized part of the berm besides making the road look prettier. Fig 7, page 17 (f) illustrates what is intended.

Depth of Treatment.—The depth of soil to be treated in the case of clayey soils will adjust itself according to the depth of penetration of the wheels.

In the case of sandy soils, however, it is suggested that the depth of treatment should be about 4½ inches. It is obvious that the incorporation of coarse material, along with that of the fine ingredients. will be cheaper than if both are incorporated separately. An effort should, therefore, be made to combine the two processes whenever funds permit. Where coarse material is expensive, it may be added in the top 3 inches only.

It would help in making a systematic attack on this big and important work, *viz.* the improvement of the unmetalled berms of metalled roads, if a record of treatment is kept in the form as per fig. 8, page 18 (f).

Conclusion.—In conclusion, it is felt strongly that within the usual ordinary maintenance grant, it is possible, by careful organisation, to gradually improve the berms, to a high standard of structural stability during the course of a few years.

If a scheme has been already drawn up and it is consequently known what admixture is required in a particular reach, the improvement of soils should become a matter of routine working.

It is true that this process will involve more labour than is ordinarily required for putting the dry *pushta* on the berms, but once this is done, the berm will naturally wear better and thus need less frequent attention.

The incorporation of coarse material will certainly involve extra expense, but it will also correspondingly increase the life of the berm. The worst miles in each section could be taken up first and periodical concentrated work done on them by mobilizing the adjoining gangs. As each mile is improved, it will leave the gangs free to spend more time on the improvement of the unimproved miles.

After the entire milage has been thus stabilized, it will be possible to reduce the gangs considerably, the process of maintenance of the berms resolving itself into putting a thin layer of stabilized mixture of soil and coarse material, say, once a year, and occasional patching of potholes etc.

As the element of danger to traffic will be entirely removed where the berms are thus stabilized, the demand for the widening of metalled roads will be considerably reduced. It will thus be possible, not only to do the necessary widening within the scanty funds available for it, but also perhaps to divert a part of these funds to the improvement of the berm, in order to accelerate the progress, with a view to keep down the demand for a far more expensive alternative *viz*, the increasing of metalled width.

Incidentally, it will be possible to tar the berms thus stabilized under traffic for some years, after rolling down a thin skin of stone, say, 1 inch only, on the wet surface. This will reduce the cost of widening very considerably. That the berm is ready to receive surface treatment will be decided by its own behaviour. If the surface does not corrugate too much it will be an indication that the foundation has got stabilized to a sufficient depth under traffic, to take up the prevalent loads without detrimental deformation, which in turn would be a clear indication, that the surface can be safely sealed.

9. **Summary of Procedure** :—(*a*) The first thing to do is to classify the soils into the various classes described before, by carefully questioning old road inspectors, mates and coolies regarding the exact behaviour of each mile or part thereof during different seasons.

(*b*) A survey should then be made of available admixtures round about the site where required. Local residents should be very helpful in this.

(*c*) 20 percent admixture of clay should be done in dry powdered form to dry powdered soil. Granular material to the extent of 40 percent by volume of the total crust should be added at the same time if possible and the whole mixture rolled while moist.

(*d*) Admixture of sand and coarse material should be done by spreading a thin layer at a time on the soft wet clayey soil, and letting the traffic work it in. This is best done during rains when a small *bund* should be made at the outer edge of the portion to be stabilized, so that water will stand over it and help in softening the soil.

(*e*) Maximum possible compaction of soils not containing coarse material is obtained by rolling them with a Sheeps-foot roller at optimum moisture.

(*f*) The stabilized berm should be sloped out at 1 in 40.

(*g*) Water should be splashed on the berms occasionally as a matter of regular practice wherever it can be gravitated along the road from irrigation channels.

(*h*) The classification, the sources of admixtures, the subsequent treatments and the results thereof should be carefully recorded in the form as per fig. 8, page 18 (f).

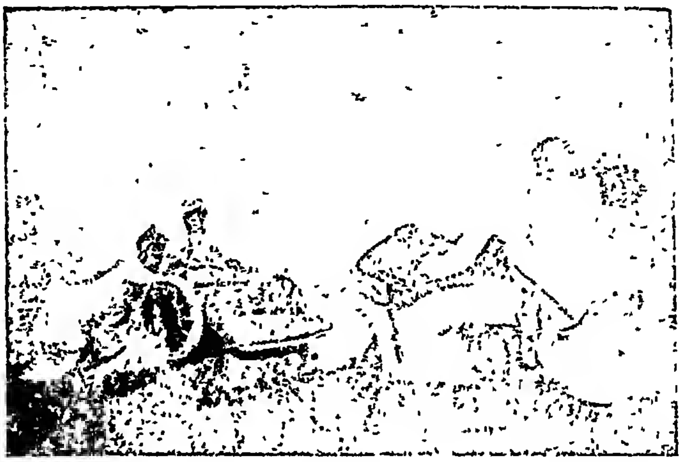


Figure 2.
A general view of the sheeps foot roller working.

Figure 3.
Roller in the beginning of the operation with its feet sunk completely into the loose soil.

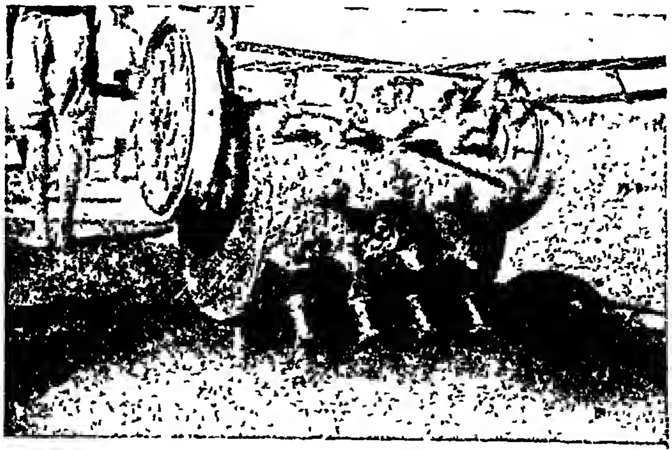


Figure 4.
Roller towards the end of the operation with its feet-penetrating only a little bit in the compacted soil.

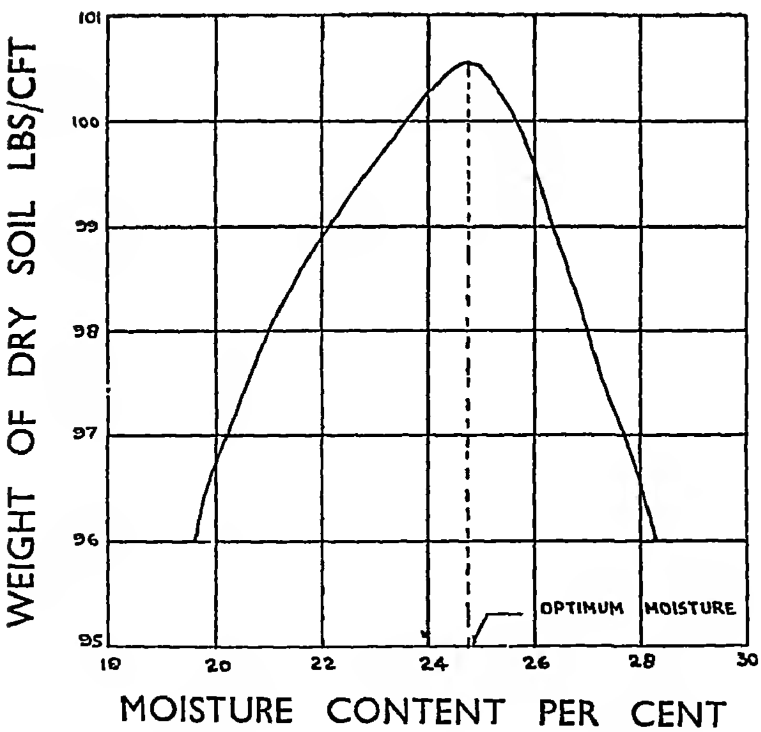


Figure 5.

SPECIAL IRON RAMMER
For
COMPACTION OF SOIL MIXTURE.

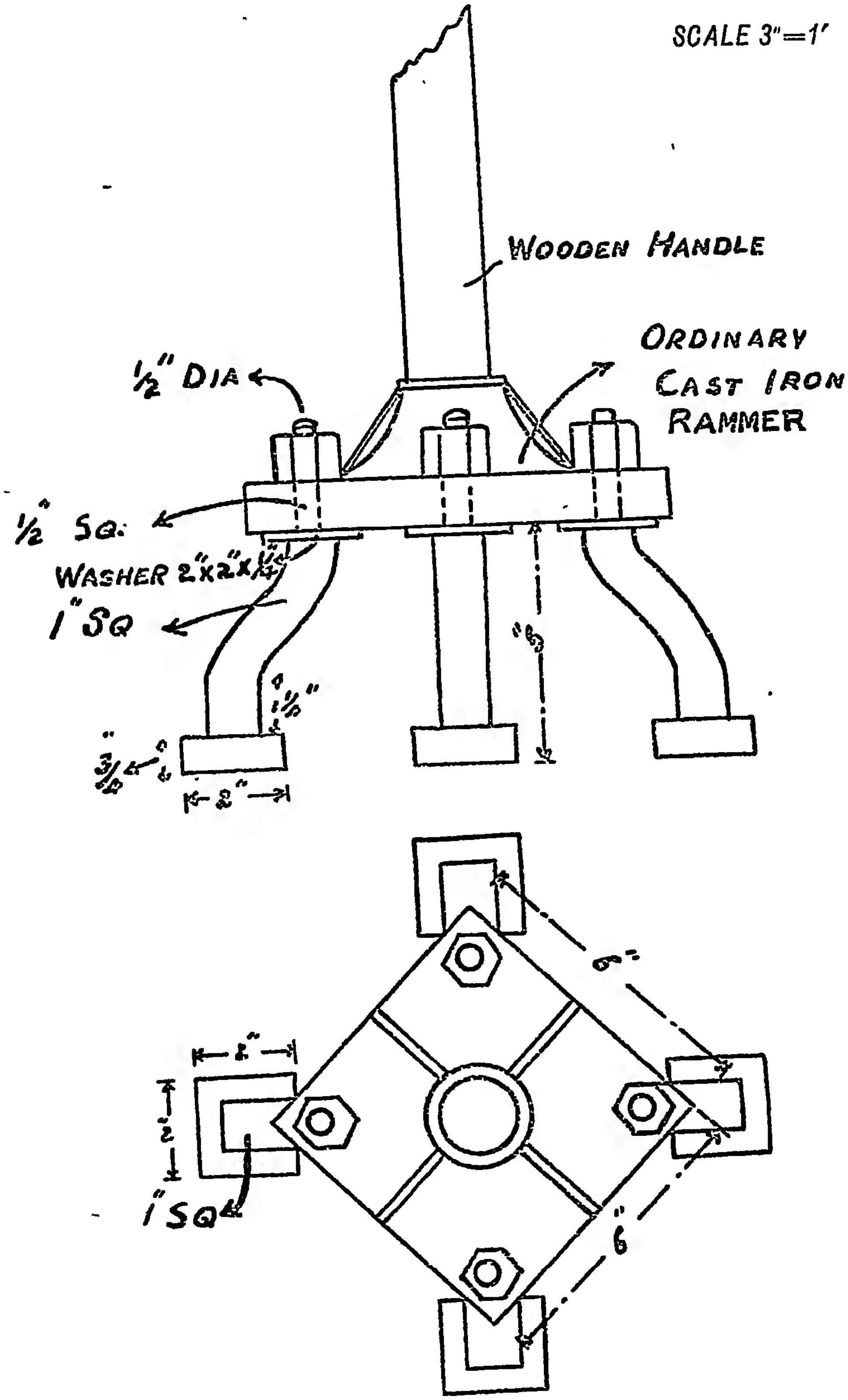
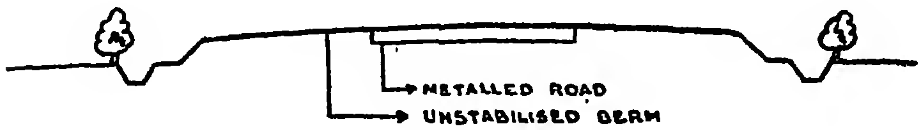


Figure 6.

SECTION OF ROAD AS AT PRESENT



SECTION OF ROAD PROPOSED

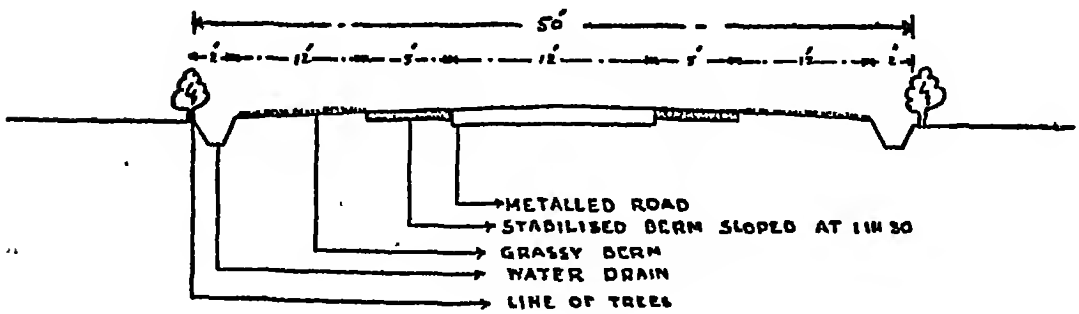


Figure 7.

STABILIZATION OF BERMS.

*Name of Road*____________________

Mile	Behaviour of soil in year_____.	Class.	Proposed treatment	Sources of admixtures.	Date of treatment.	Behaviour in year_____.	Further if any treatment with date.	Behaviour in year_____.	Further treatment if any with date.	Behaviour in year___.	Subsequent behaviour and whether fit for surfacing.

Figure 8

DISCUSSION ON PAPER F—39

Mr. S. R. Mehra (Author):—During the course of my work in the Board of Communications, Punjab, in connection with soil research, I had the opportunity of holding discussions with many District Board and Provincial road engineers, and also of questioning at length the local road maintenance staff on the subject of soil stabilization and the most practical way of introducing it.

The one point, upon which opinion was unanimous, was that there must be a simple practical method of classification of soils. The method of analysis outlined by me last year in the paper that I presented before this Congress at Calcutta does not appear to be universally acceptable at the moment, because it involves the use of laboratory testing, which is not within easy reach of the average road engineer. Besides this, the interpretation of soil constants and their use in designing a soil mixture require that the engineer concerned should have a certain amount of experience of soil behaviour with reference to the American Code of Practice.

With this difficulty in view, I took up the task of evolving a simple method for the general classification of soils, which I have described in the paper, I am now presenting. On page 4 (f) of the paper I have stated :

"Stabilization work according to this scheme has been started on several roads in the Punjab, and it is hoped that the result of the effort will be reported at the time of the Congress."

But I am sorry to have to say that it has not been possible to make appreciable progress in this direction for various reasons, one of them being the commencement of war which, for a time, affected even the ordinary maintenance estimates. Recently, however, I have started work on the silty berms of the Lahore-Ferozepore road, which is easily one of the worst roads of the Province so far as dust and mud on the berms are concerned. The work is costing me about Rs. 900 per mile for a total width of 5 feet on each side, inclusive of the pay of road maintenance gangs employed on it and of the cost of *kankar* at Rs. 10 per 100 cubic feet.

It is too early yet to say whether this mixture is going to stand up to both the bullock cart and the motor tyre traffic; but there appears no reason to assume that it will be a total failure, because if any damage does occur from time to time, it can be easily set right in the course of ordinary maintenance by the use of a little water and a hand rammer.

One point that may straightaway be raised against my paper is that I am advocating the use of a new method of maintenance without trying it out myself to any appreciable extent. My reply to that is that the method is not at all new. It is a direct deduction from the American research on earth roads over a period of more than 10 years. America has constructed thousands of miles of earth and gravel roads according to the system they have evolved and they have obtained a considerable amount of success with them.

It will probably surprise some of you to learn that over 95 per cent of the total milage of roads in Norway and Sweden are gravel roads; and having seen with my own eyes the wonderful improvement, that has been made in the service value of hundreds of miles of gravel roads in each of these two countries, by a reproportioning of the materials on the American system essentially, I cannot but be a firm believer in the efficacy of the system. Further, the small lengths that I have tried have proved fairly successful.

In any case, my object in writing this paper was to give to the members of this Congress a system based on accepted fundamentals, with the help of which they could carry out experiments themselves individually. For, in my opinion, the only way of giving a fair test to a method, which aims at solving one of the gravest road problems of this country, is to try it out in as many different localities and climatic conditions as possible. We could then pool our experiences and see in what directions the method needed improvement.

It is not at all claimed that the method outlined will give the ultimate solution of our *katcha* (earth) road problem, but it is certainly hoped that it will be a step in the right direction. If, by the use of this method, we are able to actually handle soil as if it was a building material, and then by actual experience begin to correlate its behaviour to its physical properties, we shall before long be in a position to appreciate the more scientific use of laboratory testing.

I trust that the members will keep the above points in view while discussing the paper.

Mr. P.V. Raju (Madras):—The main difficulty in this matter is in determining the best way to treat any particular soil for stabilizing it. This is best ascertained, and most economically, in a laboratory. We want, therefore, soil mechanics laboratories. The establishing of one laboratory at Lahore is a step in the right direction. We must have many more. One for each Province would certainly not be too many. On the continent of Europe there are very well equipped laboratories practically in every country. I visited those in the Hague, Paris, Berlin, Vienna and Zurich during my visit to those places. They are more or less made a part of the College of Engineering laboratories with a Government subsidy. The machinery used is very simple. Soil mechanics laboratories, apart from dealing with road problems, deal greatly with soils connected with Irrigation, such as, determining the correct grade of materials to be used to get a most economical mixture for an earthen dam, the correct slope to be given for bunds, forming watertight linings of channels, and so on.

I saw an interesting example of soil stabilization practised in Holland. In the Zyder Zee Reclamation areas, which they call Polders, the chief material used for the formation of road embankments is sand. More than half of Holland is below sea level, and the Polder areas are 5 to 8 meters below mean sea level. No hard substance can be procured for soling or forming a suitable sub-grade. The Zyder Zee area is the delta of three rivers, and you can imagine what the conditions would be like. Metal can be held only on the north-east portion of Holland adjoining Germany, and transport makes it costly. The Dutch are, therefore, resorting to a special method of burning street refuse to form clinkers which they use as matrix for the wearing coat with bitumen or cement. When such is the difficulty of getting the matrix required for the wearing coat alone, the difficulty for soling and forming hard sub-grade can be easily imagined. They, therefore, resort to stabilizing sand with an admixture of clay and cement. The method, briefly explained, is as follows. Clay, which is obtained from the bed of the lake at Zyder Zee is pulverised in a grinding mill (ordinary mortar mill) in a dry state and mixed with sand in the proportion of 1 of clay to 2 of sand and put into a mixer wherein 5 per cent (of the total mixture) of cement and a small quantity of water is added to make it into a dry mixture. This is laid on a compacted sand embankment in a

layer of 4 to 6 inches, and consolidated with a tamping machine such as we saw during our visit to Poona. The mixture was as dry as that we saw at the Hanging Gardens used for moulding flower pots. It is then cured with water. They laid a surface wearing coat of $1\frac{1}{2}$ inches premix asphalt on it and it made a good road surface for Autobahns. We are not interested in the wearing coat but only in the method used for sand stabilization. Before the proportion of clay and cement, used for getting best results, was arrived at, the materials were subjected to laboratory experiments.

In most parts of India the road side berms are either over-sandy or over-clayey. All that is needed is to determine the correct proportion of sand and clay necessary to make a good mixture and the extent of cement needed to stabilize it. Laboratory is the place for determining this. May I wish that the members of the Congress will endeavour their best in the establishment of the soil mechanics laboratory as a necessary adjunct to the road engineer ?

I have described only one method of stabilization. There are several other methods. For road berms, this elaborate method which I have described is not necessary. Having determined the correct mixture of cement necessary, the mixture may be ground in mortar mills, laid and consolidated by hand without recourse to any machinery. Such stabilization of road berms would lead to economy in the construction of modernised class II and class III roads. The modernised class II and class III roads may be made of just sufficient width to take only the heaviest traffic. Perhaps 9 feet will be ample for a single line of traffic with 3 feet of stabilized margin on either side giving a road of 15 feet. This would be ample for overtaking vehicles without getting over soft margins.

Mr. Ali Ahmed (Assam) :—I have only a few remarks to offer. If you will refer to page 8 of the paper, at the bottom, Mr. Mehra says :

"The coarse material should be graded from 3/4 inch downwards. The following figures of grading are given as a general rough guide :—"

Now, stabilizing of earth berms with river shingle has been done by us on most of our roads, and our experience is that the shingle should not be too fine. It should be graded from one inch downwards if only the berms are to be treated. In fact, if you have it a little bigger than one inch, it does not make any difference. If Mr. Mehra is using 5-foot berms on either side, I would advocate a bigger size than three quarters of an inch, because the smaller stuff will cost you more and last much less than the bigger size.

Then, Mr. Mehra says on page 12 (f) :—

"It will be possible to tar the berms thus stabilized under traffic for some years, after rolling down a thin skin of stone, say, 1 inch only, on the wet surface".

I am afraid that is not possible. We have got a very large milage of gravelled roads in Assam, and we have been building up our crust since, practically, 1931, but we have not found it possible to coat it with tar and get it stabilized that way. We tried an experiment by consolidating 4 inches of gravel on road, first with a roller and then laying a 2-inch carpet over it. But that means expense. It no longer remains a gravel road, So, I am afraid this will not be practicable,

The third point, that I wish to refer to, is on the same page, page 12 (f), paragraph 9 (d):

"Admixture of sand and coarse material should be done by spreading a thin layer at a time on the soft wet clayey soil, and letting the traffic work it in. This is best done during rains when a small *bund* should be made at the outer edge of the portion to be stabilized, so that water will stand over it and help in softening the soil".

If you have got a clayey soil, there is absolutely no necessity of spreading any sand over it. Straightaway put your gravel, and you will find that it binds extremely well and gives you very good results.

Mr. G. D. Daftary (Bombay) :—The paper stresses the necessity of providing a soil mixture consisting of the correct proportions of earth, clay and sand for the berms so as to make them, as far as possible, stable and less dusty. The main point in laying such a mixture for such purpose is to retain a certain moisture content in the mixture to help cohesion and prevent dispersion. The author tries to attain this by occasional watering. He states that in the Punjab, canal water can be gravitated along the roadside in more than 75 per cent of the metalled miles and presumes that water is cheaply available along roadside in a major portion of the metalled miles in other provinces and states also. This presumption would be too bold, and even if water can be made available along the road, the expense to keep the berms watered occasionally will be too heavy to be of practical value.

In order to obviate this difficulty of maintaining the moisture content by occasional watering, various hygroscopic salts such as (1) common salt, (2) calcium chloride, and (3) magnesium chloride, were used in the road berms to keep them free from dust along roads leading to the Haripura Congress in Surat District, in February 1938. It was anticipated that the salts would absorb moisture from the air and keep the surface moist, intact and free from dust. The moisture-content was lost in a few days (less than a week) and the berms had to be watered to be dustless.

Crude oil was also tried with the same result.

The processes were also found to be too costly.

This is by no means the last word on the subject. It is possible by intensive laboratory work and more field experiments to obtain the optimum mixture which will keep the moisture-content in the berms in all weather and help to evolve a cheap method for ensuring stabilized and dustless berms.

My hope is based on an experiment recently carried out near Pen, a taluka town in Kolaba District of this Province, for laying a metal layer mixed with sand murum and calcium chloride for central vehicular track with the object of providing a stabilized road surface free from dust. The proposal was sponsored by 'Imperial Chemical Industries' and they recommended an experiment being made in a humid climate on a road near a creek or seashore. Furlong 6, of mile 5, of Dharamtar Campoli Road was, therefore, chosen for the purpose. The Company gave the quantity of calcium chloride, free of cost for the experiment, and they advised the proportions of the various ingredients in the mixture after tests in their laboratory. The final mixture adopted was :—

50 per cent stone graded metal;
35 per cent sand;
15 per cent murum.

Calcium chloride at 4 pounds per square yard was used. The mixture was laid in 2 layers on a foundation of 8 inches rubble and 3 inches metalling done a year before, and the cost, inclusive of that of the calcium chloride taken into account for the purpose, came to about Rs. 8-1-0 per hundred square feet, or just about the same as for asphalt or tar seal coat. It was reported to be wearing well. We are awaiting further results about the condition of the road and how it wears, because the experiment is not old enough to base any definite conclusions on it.

Rai Saheb Fateh Chand (Bijnor):—I have found that if the surface of the road is kept low at the time of construction, it helps a great deal in maintaining the berms in good condition.

Another point is whether we should have berms at all on roads on which the metallic portion is sufficiently wide. For a width over 20 feet no berms are required. What is required is protection of the edges by means of 1 to 2 feet edging with clay or brick or water-bound macadam. In the United Provinces, the Punjab and Bengal, where the width is 8 to 12 feet, we do require berms. Bullock carts prefer to go on the *katcha* portion, especially those of agriculturists, which form about 90 per cent of the total traffic in my district at least. They prefer to go over the *katcha* portion, because the bullocks are unshod, and because the wheels of the cart have no iron tyres. It is, therefore, better to provide *katcha* berms and stabilize them. In Bijnor, we stabilize sandy portions by putting 9 inches of clay. A thickness of 6 inches has proved a failure. I have treated about 400 out of 600 miles of *katcha* roads in this way and it is quite successful. When you put 9 inches of clay, it becomes like a hard metalled surface, and it makes a compact mass. We occasionally cover it up with ordinary sand and it lasts 10 years. Renewal with 3 or 4 inches of clay costs us Rs. 200 to Rs. 300 per mile, and the renewal is done after 9 or 10 years. All that is required is a coat of 1 to 2 inches of sand annually or in alternate years.

Another experiment was made by using coal clinker for the purpose; 2 to 3 inches thickness was used. It was obtained from railway stations. The cinder is taken away for mixing with lime for mortar and the material left is of ¼ to ¾-inch gauge, which is used. It lasts upto 3 years. The bigger stuff is much better than the smaller stuff. When the traffic works it up, it becomes very nice. In some places molasses, which could be had free of cost, was also sprinkled over it but it did not make any improvement.

In some marshy places, I found that the berms of the road got badly cut. Gunny bags filled with sand were used to protect the edges and the berms and proved fairly successful and the maintenance cost was reduced.

I suggest that the camber on berms should not be more than 1 in 20, preferably 1 in 30.

Mr. S. R. Mehra (Author):—Mr. Raju says that the method outlined by me is very elaborate. He seems to think, that the interpretation of

laboratory analysis and its use in soil stabilization, is a simple matter. From personal experience of laboratory testing, ranging over a period of three years, I can assure him that he is mistaken. The simplest way of preparing one's self for the correct use of laboratory data, for designing stable soil mixtures, is first to get used to the behaviour of soil. This can only come from practice and self-acquired confidence.

To expect that an engineer, not used to handling soil as a familiar material of construction, could intelligently make use of data supplied by testing laboratories, is like reaching for the moon.

Besides, before we have soil laboratories in all the provinces, as hoped for by him, it will be a very long time indeed, and during this interval, the more we handle soils, the more we shall begin to understand their behaviour, and the less foreign we shall find ourselves to the laboratory data, when at last it is actually available. The simple rules outlined by me in my paper, will enable any engineer to handle a soil and help him in understanding its behaviour.

Mr. Raju has referred to the use of brick-on-edge roads in Holland. Apparently, he thinks they will be cheaper than stabilizing the soil. The bricks used on Dutch roads are a special kind of bricks, burnt in special electric ovens, at controlled temperatures. These brick roads are actually more expensive than even concrete roads, but the reason why they continue is, that brick making is their national industry and they want to keep it up, even though it is not economical.

Mr. Raju seems to think that stabilization with cement and clay will be satisfactory. Considering bullock cart traffic, such a crust can, at best, be useful as a foundation course and can replace the soling coat, but the cost of cement alone at 5 per cent being about Rs. 2000/- per 10 feet mile, for a $4\frac{1}{2}$ inches coat and the labour for mixing and compacting being another Rs. 500/- or so, it does not compare with the usual brick-on-edge soling which costs about Rs. 3000/- complete, and is fool proof.

Mr. Raju has mentioned that on the motor-ways in Holland, all they are doing is to give a surface treatment to a cement stabilized base. It is all very true, but Mr. Raju has overlooked the fact that the width of the motorway over which this specification is being used is meant only for parking the vehicles and not for running them. The usable roadway is in concrete.

Mr. Raju says that he would like 1 inch size granular material to be used. Mr. Ali Ahmed prefers a still larger size. The grading suggested by me, allows upto 10 per cent of 1 inch stuff, but anything more than that has been found as a matter of experience in America, Norway and Sweden, not to give the best mixture, because for one thing, it is very difficult to maintain it. The whole idea in the mixture suggested by me is that you can maintain it like an earth road by means of hand spades or mechanical maintainers, due to the small size of the aggregate. The larger the aggregate, the more difficult will it be to maintain the surface.

Mr. Ali Ahmed (Assam):—We are maintaining upto 2 inches very properly.

Mr. Mehra (Author):—I do not know about that, but I wish to repeat that it is not wise to use very coarse granular material in soil stabilization.

Mr. Ali Ahmed has expressed his doubt about the possibility of tarring the berms after they have been stabilized as suggested by me. In this connection, I would refer him to the hundreds of miles of gravel roads that have recently been tarred in America, Norway and Sweden, on what they call the 3 coat system. A tack coat of high penetration tar is applied cold to the stabilized surface and allowed to soak into the crust for 24 hours, upto a depth of half an inch or so. The first and second coats of tar are then applied to this surface in the ordinary way. The method has proved successful. I have inspected hundreds of such miles myself.

Mr. Ali Ahmed has also suggested that sand is not required for stabilization, and that gravel alone should be used for the purpose. The answer to that is, that if the prevailing soil mixture is rich in clay, you must find a means to prevent the excess clay from acting as a lubricant in the presence of water and thus making the soil mass lose its stability in the wet weather, resulting in deep ruts under traffic. This can only be done by the addition of sand. Gravel is far too coarse a material for this purpose.

Mr. Daftary has expressed his doubt about the cheapness of the method of sprinkling water, for keeping up the moisture content of a soil mixture. If water is available on the roadside, as in most irrigated areas, there is no cheaper replacement for it. All that is required is that a cooly should stand in the roadside drain and splash water on the road. One cooly could easily do half a mile a day, and two thick sprinklings per month should be ample. As regards the use of chemicals for retaining moisture, it is an experimental fact that the use of calcium chloride, in the Punjab at least, is prohibitive due to its expensiveness in the large quantities required to be used. Common salt, if obtainable free of duty, could be used for winter months, but during the dry summer months, it is no use at all.

The gravel road stabilized with calcium chloride, which has cost Mr. Daftary Rs. 8-1-0 per 100 square feet, must be at a very humid place, where the quantity of chemical required is very small, if any.

Rai Sahib Fateh Chand says that the surface of the earth roads should be low. I quite agree with him in so far as the retention of the moisture is concerned. We have to see, however, that it is higher than the surrounding fields; otherwise it would get flooded during the rains and defeat the object of an all-weather road.

I agree with him when he says that berms are not required on roads 20 feet wide, and I have not advocated them.

Mr. S. Bashiram (Chairman):—The time left at our disposal is now very short and there are more papers yet to be discussed by the Congress. I will, therefore, make no remarks and content myself by thanking Mr. Mehra on behalf of the Congress for a very interesting paper.

PAPERS H—39, E—39 AND G—39

Mr. K. G. Mitchell (Chairman) :—We have got two hours,—possibly less,—for the three papers remaining and they will be taken up together for discussion. After all the three papers have been introduced, members may discuss them, and the authors can then reply.

The following three papers were then taken as read :—

PAPER No. H—39.

AN ECONOMICAL SUBSTITUTE FOR WATER-BOUND MACADAM.

BY

A. LAKSHMINARAYANA RAO,
Special Engineer, Road Development, Madras.

Where traffic is heavy and consists of both fast pneumatic-tyred motors and slow moving bullock carts with iron tyres, a water-bound macadam surface is not economical and frequent renewals are necessary to keep up the surface in a tolerable condition. The maintenance cost also runs very high.

A 2-inch renewal, 16 feet wide costs Rs. 2400/- per mile with metal costing Rs. 12/- per 100 cubic feet, and gravel costing Rs. 3 per 100 cubic feet on the average, as per details below. If it be necessary to lay such renewals every alternate year, the maintenance cost per mile will be Rs. 1400/- as the surface has to be blinded every month with gravel, six months after consolidation, and patched up here and there in the second year. This figure must be accepted as a very high figure for the kind of surface which we provide for the traffic.

	Rs.	A.	P.
COST PER FURLONG :—			
1760 c. ft. of blue granite metal at Rs. 12 per 100 cubic feet ..	211	0	0
440 c. ft. of gravel at Rs. 3 per 100 cubic feet.	13	0	0
10560 sq. ft. of picking, sectioning, spreading metal on gravel and consolidation, including carriage of water when water is within half a furlong at Rs. 0-11-3 per hundred square feet.	74	0	0
Sundries	2	0	0
Rs.	300	0	0

The cost per mile is, therefore, Rs. 2400/-

Is it desirable, then, to persist in continuing a specification which requires such disproportionately large amounts on maintenance, if the same can be avoided by adopting better specifications? The answer is a clear "No". What then is the remedy?

Attempts to change all the important roads into ideal roads are foredoomed to failure from the financial point of view. Hence it is imperative that methods and specifications are adopted to suit the traffic conditions and the funds that can be spared for roads by our Governments. Our aim should be to have real roads first where we are having mere apologies for roads, at least in the case of important communications.

Stretches of roads have to be classified into three classes :—

(1) Roads with very heavy traffic of over 1000 tons per traffic lane of 10 feet width per diem.

(2) Roads with medium traffic of 500 to 1000 tons per traffic lane per diem.

(3) Roads with light traffic of less than 500 tons per traffic lane per diem.

The surface to be provided should be the one suited to the traffic *i.e.*, the one which can stand the traffic with minimum of annual maintenance. I particularly mention stretches of roads, because there is no limit to the length of a road and in one long road, a stretch may have very heavy traffic, while a neighbouring one may have medium traffic and a third stretch may have light traffic.

When the traffic is over 1000 tons per traffic lane of 10 feet width, roads should be built of cement concrete. It costs Rs. 30/- per 100 square feet for a 6"-4"-6"-4"-6" section or Rs. 25,350, in round figures, per mile 16 feet wide near Madras, and the cost of maintenance as computed from that of a bit built in 1931-32 on Great Southern Trunk road is Rs. 50/- per mile. The cost of cement is taken at Rs. 37 - per ton excluding cartage, cost of coarse aggregate $1\frac{1}{2}$ inches to 1 inch gauge and $\frac{3}{4}$ inch to $\frac{1}{4}$ inch gauge (proportion 2 : 1) is taken as Rs. 14-1-3 per 100 cubic feet and fine aggregate at Rs. 4/- per 100 cubic feet. Cement concrete roads have been found to stand heavy traffic very well and the sooner all the roads with very heavy traffic are rebuilt as cement concrete roads, the better for the road-user and the road maintaining engineer. But there is a large milage of roads on which the traffic is between 500 and 1000 tons per traffic lane of 10 feet and the problem is the proper maintenance of these roads. (The length of such roads in the Madras Presidency is at least 2000 miles).

As already stated water-bound macadam is unable to stand the *strain*, and, also, the maintenance charges are high. Cement concrete is out of consideration from the practical stand-point. So also is bitumen concrete going under various names, such as Shell-crete, Shell-macadam, Premix, Shell-sheet, Tar-carpet, Tar-crete, etc. Painting by various kinds of bitumen or tar or surface dressing, as it is commonly called, is found to be a failure under heavy iron-tyred double bullock-cart traffic.

The author has been trying for the last 3 years to develop a type, where the bitumen may be used as a binder alone and which may require the minimum quantity of bitumen, and has adopted the following specification which is placed before the Road Congress for consideration and criticism. This type of construction may be called "BITUMEN BOUND MACADAM". This has been tried only on water-bound macadam roads, where hard metal has been used and the object is to give an enduring, fairly smooth and dustless surface, which can be maintained at a fairly low cost, in a fairly good condition.

SPECIFICATION.

The surface of the old road is picked up to a depth of 2 inches and well sectioned to give a camber of 1 in 48. The surface is then rolled two times. Granite or some other equally hard type of metal, broken to $1\frac{1}{2}$ inch cubes is then spread and the surface is well rolled by a 10-ton roller water being poured over the road just in sufficient quantities, to render the surface of the road below the metal wet and to allow the slurry to work up to $\frac{1}{2}$ inch below the top level of the metal surface. Care should be taken to see that too much water is not added *and the slurry does not come to the top.* 20 to 30 trips of the roller are found to be sufficient. Quantity of water depends on the hygroscopic condition of the soil.

The surface of the road is then closed for traffic and allowed to dry for about 48 hours. After the surface is completely dry, the dust and vegetable matter is blown by the winds and any slurry within half an inch of the surface is removed by coir-brushes and bass-brooms. Then bituminous material of 70 to 100 penetration, heated to 350 degrees Fahrenheit in a boiler, is sprayed over the surface of the road at the rate of 48 pounds per 100 square feet. As the spraying advances, ½-inch to ¾-inch granite or hard metal chippings are spread over the surface in one layer. The coolies pack the chips well with hand, as the bituminous material becomes less hot in half an hour. Rolling is then done till the chips are well embedded between the stones. 30 to 40 trips of the roller are found sufficient and about 2.25 tons of bitumen per furlong, 16 feet wide are used. Traffic is then allowed on the road. (Spraying is best done between 10 a.m. and 3 p.m. and no spraying should be done in the cool hours of the morning or evening).

On the second or third day, the surface is again rolled in the midday for a couple of hours.

Various stages of the work are illustrated in figures 1 to 10.

The cost of the work per furlong 16 feet wide is as follows :—

	Rs.
1760 cubic feet Blue granite metal, at Rs. 12 per 100 cubic feet.	211
600 cubic feet Blue granite chips ½-inch to ¾-inch at Rs 19 per 100 cubic feet.	114
2 25 tons of bitumen at Rs. 120 per ton.	270
Consolidation of 105 65 square feet at Rs. 0-15-0 per 100 square feet as per details below.	99
Sundries	6
Total Rs.	700

Therefore, the cost of one mile of Bitumen Bound Macadam will be Rs. 5600/-. and the cost per 100 square feet will be Rs. 6/10/-

Detail of the rate of 15 annas for consolidation is as follows :—

	Rs.	A.	P.
100 square feet picking, sectioning, re-forming the road surface, spreading metal and consolidating including watering in the first stage, where water is available within half a furlong.	0	9	8
100 square feet spreading chips after screening the dust and hand packing.	0	1	0
2.25 tons spraying bitumen including cost of coal	0	3	6
Sundries.	..0	0	10
Total	0	15	0

Note—(1) When the surface is pot-holed, the pot-holes should first be patched up before the above specification is commenced.

(2) There should be at least 6 inches of the metal crust on the road, of which at least 3 inches should be of hard metal.

(3) The specification does not apply to soft varieties of metal such as lime-stone, laterite, etc.

It is observed that in 2 or 3 months, the surface gets well ironed under the steel tyres of the double bullock-carts and will stand mixed traffic very well.

One great advantage in the adoption of Bitumen Bound Macadam is that the steam and motor road rollers and their drivers can be given work during the hot months, as this kind of work is best done during that period, when no water-bound macadam can be done.

The water required for the initial stage of Bitumen Bound Macadam is very little and can easily be carted even from long distances at a small cost. The surface keeps up well for 2 years and only in the third year the surface requires dressing. The average annual maintenance charges of this type of road is Rs. 1000/- per mile as per details given below against Rs. 1400 per mile in the case of maintaining water-bound macadam.

Annual maintenance charges :—

First year for patching per mile —

1 ton of bitumen at Rs. 120 per ton.	Rs 120
200 cubic feet chippings, ¼-inch to ½-inch at Rs. 22 per 100 cubic feet.	Rs. 44
Labour.	Rs. 36
Total.	Rs. 200

Second year for patching per mile —

1½ tons bitumen at Rs. 120 per ton.	Rs. 180
300 cubic feet of chippings, ¼-inch to ½-inch at Rs. 22 per 100 cubic feet.	Rs. 66
Labour.	Rs. 54
Total.	Rs. 300

Third year for surface dressing—

3600 cubic feet of chippings, ¼-inch to ½-inch at Rs. 22 per 100 cubic feet.	Rs. 792
11.2 tons of bitumen at Rs. 120 per ton.	Rs. 1344
Labour for spreading chips and cost of spraying and rolling.	Rs. 364
Total.	Rs. 2500

Total for three years Rs. 3000/-

or Rs. 1,000/- per annum.

The extra cost is the initial outlay of Rs. 5600/- per mile. The savings in the maintenance bill by Rs. 400/- per mile make it worthwhile to invest the initial cost.

This specification was first tried by the author in February 1927 in Kistna District and it has been standing well upto date. This year the same

specification was tried in the Great Southern Trunk road for 14 furlongs and on Great Western Trunk road for 3 furlongs where the traffic intensity is 1806 tons and 1140 tons respectively per traffic lane of 10 feet, and it has, so far, been standing very well without any maintenance charges.

It will have to be stated in this connection that the term *bitumen* used in this paper includes coal tars also and it is not proposed to deal in this paper with the relative merits of these materials.

Excess of bitumen causes bleeding and the surface gets wavy very soon, hence care should be taken not to use more bituminous material than what is required.

It may perhaps be stated that the above specification is only a sort of grouting. But it may be noted that for grouting 2 inches deep, 56 tons of bituminous material is necessary while for the above specification only 18 tons per mile, 16 feet wide, is sufficient.

As stated above, the savings in the maintenance cost alone will warrant the use of the above specification in place of water-bound macadam when the traffic borders on 1000 tons per mile per traffic lane, 10 feet wide, and where metal costs Rs. 12 per 100 cubic feet. Where metal is more costly, it is clear that the need for substitution of water-bound macadam by bitumen-bound macadam is greater under heavy traffic conditions.

In addition to the above, dust nuisance is completely overcome and the saving to the public health bill of the country must be great

PLATE 1.

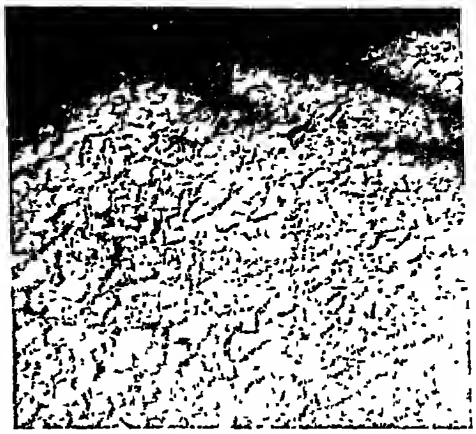


PLATE 2.

Plates 1 and 2. Metal spread, rolled and allowed to dry.

PLATE 3.

Spraying in Progress.

PLATE 4.

PLATE 5.

Plates 4 and 5. Chips being spread over bitumen-sprayed surface.

PLATE 6

Chips spread and hand-packed.

PLATE 7.

Rolling commenced.

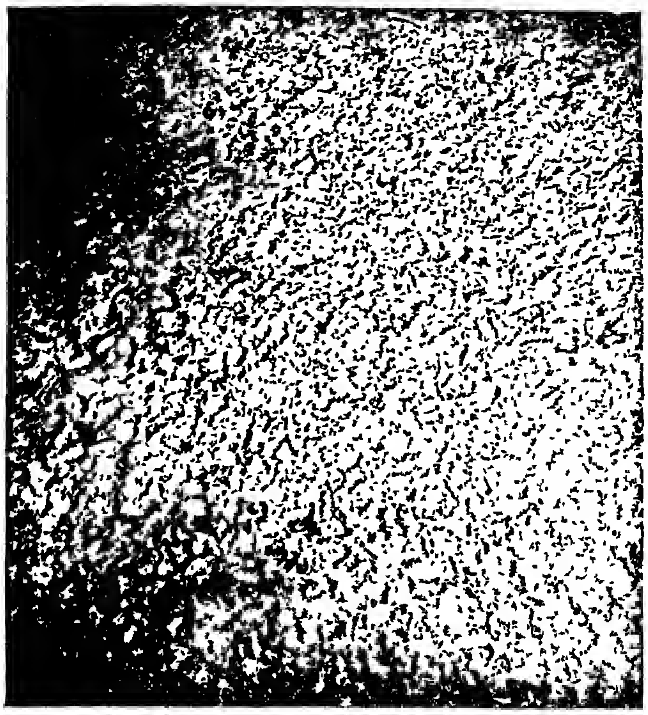


PLATE 8.

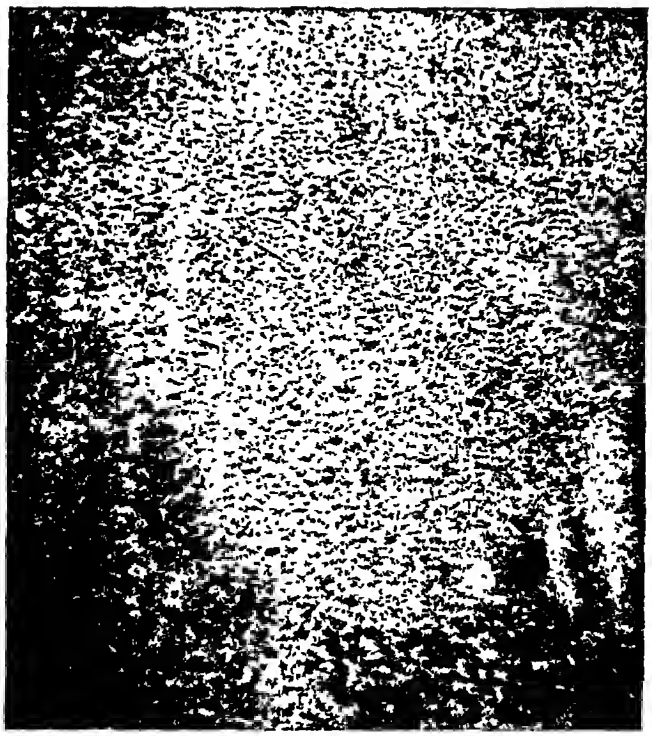


PLATE 9.

Plates 8 and 9. The surface as rolling advances.

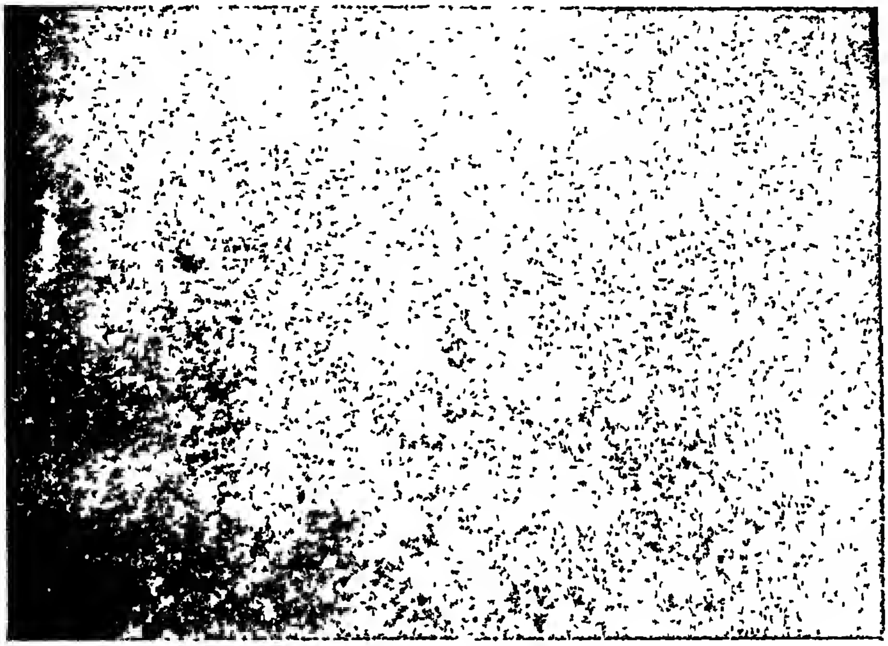


PLATE 10.

The road surface thrown open to traffic.

PAPER No. E—39

PRESENT DAY METHODS OF BITUMINOUS ROAD SURFACING WORK IN CHOTA NAGPUR, BIHAR.

BY

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At the last Roads Congress held in calcutta in February, 1939, a very useful paper on "Some aspects of Bituminous road construction in India" was presented jointly by Colonel G. E. Sopwith and Mr. W. A. Griffiths. The paper claimed to deal with the general principles only and not to set out specifications, the reason given being that with the continuous research and practical experiments which are continually being tried, frequent changes in the methods of treatment occur and therefore any specifications which may be fixed may become partially out of date before the code has passed its infancy, It is, however, to be remembered that side by side with experimental works some generally accepted methods, may be differing in different parts of the country to suit the conditions prevailing in each, are being followed in road surfacing works which are being done on fairly large scale in the different provinces and areas concerned. It, therefore, seems necessary that for each province or area the proper methods evolved so far should be laid down in the form of specifications for the guidance of the people engaged on this work and there should be no difficulty in making modifications hereafter and keeping these up-to-date with the help of results of experimental works in hand. These specifications should not only be necessary for proper execution of the work in the area to which they apply but may prove of at least some value to others engaged on similar works in other areas for comparing notes, trying details of methods proved useful in other parts as found applicable to their own condition and in this way full advantage can be taken of others' experience in improving one's own methods. It is with these aims that the author has drawn up detailed specification of the road surfacing work as is being done in the Chota Nagpur Circle of Bihar P. W. D., and in presenting the same to the delegates of the Indian Roads Congress through this paper, comments and constructive critisisms are invited which may prove useful to us in improving our methods.

It may not be out of place to mention here a few other things connected with our road surfacing work for information and comments of the delegates.

Till early 1938, the practice in Chota Nagpur was to surface only those lengths of the water-bound metalled road which had been just reconsolidated in the preceding season for such work, and generally more length was reconsolidated in a season than could be surfaced in the next surfacing work season. The result was that not only newly consolidated surfaces were left to deteriorate for being reconsolidated again after 2-3 years but

water-bound surfaces of older consolidation which were in sufficiently good condition to be surfaced immediately were never considered for such work. This naturally retarded the progress of surfacing even of those roads which were decided to be wholly surfaced. During the working season of 1938, for the first time experimental surfacing of old consolidated water-bound was tried and so far the result is considered successful. Certainly, water-bound macadam which (though somewhat rough compared to that newly consolidated) has stood the traffic for some years without deterioration by corrugation and pot-holes, should give a better foundation for surfacing work than a newly consolidated metal which may not have been as sound as one would wish it to be and whose weak spots have not been disclosed by traffic. Lengths of road were selected having been consolidated a few years back and having very nearly as good a surface as if newly consolidated and these where surfaced by the ordinary method by giving a primer seal and second seal. A stretch of road consolidated as far back as 1929 though roughish but sound in other ways was also surfaced by the mix-in-place method and this also is standing well. With the success of such works, not only the reconsolidation work has been restricted to only so much as can be surely surfaced next season with funds available but from savings affected thereby surfacing of old consolidated lengths is also being continued and thereby the surfacing programme has been greatly accelerated.

In some quarters doubt exists whether a primer seal coat on an old consolidated water-bound macadam surface will penetrate adequately as it does into a newly consolidated surface. To test this some lengths were consolidated in March and were given primer seal in April, and reseal in May, 1938. Last May the penetration in this case and also that of priming in 1938 surfaces consolidated in 1936 and 1929, were ascertained and no appreciable difference was noticed. The depth of penetration was found to depend mainly on the depth to which the interstices between top layer of metal are opened up in preparing a water-bound macadam surface for receiving the primer seal and also a little on the weather conditions in which the primer seal is laid. In hot sunny weather the binder remains hot longer and the oils in it soak a little more in the blindage.

Experiments were also made in 1938 in the use of sand together with stone chips in blinding. In this case it is necessary to lay the chips directly on the binder and then to roll these almost fully and then to spread sand uniformly well broomed to fill the voids between the chips. After rolling a few times more the work is completed and opened to traffic. There is a little saving in cost but the non-skid quality of the surface is diminished. It is yet to be seen how the introduction of sand affects the life of the surface which can only be judged after a year or two more.

Representatives of binder manufacturers suggest the use of 1-inch to 2-inch premix carpets where surface dressing even on good strong macadam road is unable to stand iron-tyred bullock-cart traffic. But there is one point about such construction which is not clear. Evidenty a good strong macadam with trap or good quartzite metal will stand an appreciable amount of iron-tyred bullock-cart traffic as a foundation and it is the thin surface dressing with $\frac{3}{4}$-inch to $\frac{1}{2}$-inch chip carpet which is cut through, to improve which the 1-inch to 2-inch premix carpet is recommended. What is to be done after the wearing surface of the—say 2-inch premix work wears and requires making up? Are we to (i) dig up and re-do

the premix carpet, or (ii) put another on the old one or (iii) give only a wearing course with surface dressing and $\frac{3}{4}$-inch to $\frac{1}{2}$-inch chip carpet. Certainly, (i) will not only be expensive but troublesome, (ii) will also be expensive and if continued every three years on an average will go on raising the level of the road and (iii) would, bring us back to the same surface dressing which will not last any appreciably longer than if it had been laid directly on the water-bound macadam. Any information on successful and cheap methods of upkeep of thicker premix carpets and on grout-work would be interesting and useful.

The specification mentioned above will be found at Appendix I [page 4(e)].

APPENDIX I

SPECIFICATION FOR SURFACE DRESSING (SEALING AND RESEALING) OF WATER-BOUND MACADAM AND SURFACED ROADS IN THE CHOTA NAGPUR CIRCLE

I. COLLECTION OF BLINDERS.

(1) (a) **Stone chips.**

Stone :—The stone shall be taken from the quarry specified in the accepted tender and shall be hard and tough; free from parallel fracture, crystal cleavage, course grain, earthy matter, moss and such impurities.

Trap, quartzites of any colour, fine-grained rocks like diabase, dolomite, phenolite etc. are all suitable, white quartzite commonly known as bone, is also satisfactory. Quartz, Felspar and metamorphosed sedimentary rocks, black or other micaceous schists and course grained gneiss are unsuitable for making chips.

Breaking by manual labour :—This should be as far as possible done on the roadside by bringing boulders or ballast from the quarry, otherwise at the quarry itself. After being suitably broken with 2—3 pound steel hammers to give chips of required sizes to suit the binder to be used the grading is done by screening through screens of the undernoted sizes of square mesh (clear space between wires and not from centre to centre) placed at 30 degrees to the horizontal.

1-inch Chips to wholly pass through a screen of 1¼-inche mesh and be wholly retained on a screen of 3¼-inch mesh. These would be suitable in some of the mix-in-place surfacing work.

¾-inch Chips to wholly pass through a screen of 1-inch mesh and be wholly retained on a screen of ½-inch mesh. These would suit original seal coat over roughish old water-bound macadam with Road Tars and for seal and reseal work with straight bitumen, unless the latter is to be laid on old, hard and glazy surface without a previous tack coat where ½-inch chips would be preferable.

½-inch Chips to wholly pass through a screen of ¾-inch mesh and be wholly retained on a screen of ⅜-inch mesh. These would suit for reseal works with Road Tars.

⅜-inch to ¼-inch Chips :—Anything which is not merely stone dust and is retained on ¼-inch mesh screen. These suit for being given over finished work for filling interstices between bigger chips and stopping 'bleeding.'

Breaking by power-driven Granulator:—For this purpose stone spalls have to be collected from the approved quarry and brought to the site where the Granulator has to work preferably near the roadside. The size of spalls would depend on the size of

Granulator available. For a 6 H.P. 8" × 2½" Granulator, spalls not bigger than 6" × 4" × 2", are suitable. Spalls should neither be cubical nor roundish in shape. Granulators are generally provided with automatic screening arrangement for the outturn and chips obtained are those which pass through round holes of 1", ¾" and ⅜" separately and free from stonedust and no further screning is required.

Chips obtained from Granulators are more uniformly and correctly graded than hand-broken chips screened through square mesh screens placed at 30 degrees.

(b) Natural and quarry gravel :—When stone suitable for making chips is not available within reasonable distance from site of work, say up to 5-6 miles, and cost of chips is likely to be unreasonably high, natural or quarry gravel shall be collected from the place specified in the accepted tender and shall consist of as hard and tough pieces of stone as could be had. These shall have to be well-washed in water to free from all mud, and earthy matter and will be screened in proper sized mesh screens to give the specified grading as mentiond above for the freshly broken stone-chips. Such blinding material can, however, only be used with Road Tars and not with bitumen binders.

(c) Sand :—This should be clean, course and free from admixture of earth and passing other foreign matter passing through 1/10 inch square mesh screen and retained on screen having 196 meshes to the square inch. It shall be used for blinding primer seal binder, stopping 'bleeding' and also for final finishing blinding of other surfacing work, if specified where stone fine chips as received from Granulator is not available.

(2) Transportation :—The chips shall be transported by Motor vehicles or animal-drawn carts, care being taken that no chips are dropped on any portion of the road during transportation.

When whole of the carting under the contract is done by means of animal-drawn vehicles equipped with pneumatic tyres, the contractor shall receive an additional payment of annas four per hundred cubic feet by stack measurements.

(3) Stacking of Chips :—

(*a*) Normally chips shall be placed into box frame with internal measurement of 5′-1″×5′-1″×1′-1″, and will be struck flush with the top of the frame and the frame removed. Such a stack will be measured as 25 cubic feet.

(*b*) All stacking will be upon, clean, levelled or evenly sloped firm ground on the roadside land clear of the crest of road formation (including the normal 11 feet and 5 feet flanks) and on the side of the narrower flank. Where no suitable roadside land beyond the flank is available for such stacking, written order of the Sub-Divisional Officer must be obtained before any stacks are made on the flanks, but this will be confined to narrow flank, the wider being kept clear of all obstruction for the use of traffic at all times. The stacks shall be made as equidistant as possible within the length of the road on which the chips have to be laid. All stacks will be free from oversize chips and

within certain limits of undersized chips also from what is specified, and shall contain no chips of weathered or soft-stone, flat-shaped, dirt, mud, straw, vegetation or other undersirable matter. As in screening with the smaller mesh screen placed at 30 degrees some smaller chips are bound to be carried down with bigger ones, these need not be objected to unless they are excessive. These accommodate themselves in voids of bigger chips and hardly add to the bulk of the stacks.

(c) Where space does not permit to make 25 cubic feet stacks, 10 cubic feet or $12\frac{1}{2}$ cubic feet ($2'\text{-}6\frac{1}{2}'' \times 5'\text{-}1'' \times 1'\text{-}1''$ frame) stacks may be made with the previous permission obtained in writing from the Sub-Divisional Officer.

(d) All collections must be complete and finally measured and checked at least 15 days before actual date of starting surfacing work according to programme.

(4) **Rate of Payment:**—The schedule rates include quarrying the stone, breaking to size, screening, transportation, stacking, payment of royalty to the proprietor of Mineral rights, payment of compensation for transport through fields and all other incidental charges and the tendered rate should be inclusive of all such charges.

II. Collection of Binders.

(1) **Materials** :—(a) Straight bitumens for hot application such as Mexaphalt 80-100 penetration, Socony 105 and others of similar properties are suitable for seal coat over primer seal or reseal work where stone-chips of really good quality are available. It would be uneconomical to use such binder with weak stone-chips.

(b) Road Tar Nos. II and III for hot application are suitable for seal coat over primer seal or reseal work where stone-chips are not of the best quality and also where freshly broken chips are not possible and natural and quarry gravel have to be used. Of course, there is no bar against using road tars with best quality chips but to get the best out of such chips it is advisable to use binders which take longer time to become hard and brittle than Road Tars.

(c) Road Tar No. 1 for hot application is suitable for primer seal work on water-bound macadam surface.

(d) Cut-backs like Socofix, Liquid Asphalt No. II, and similar others are for cold application which are said to be capable of fluxing and reviving old surfaces which have become hard and are only suitable for use in special situations.

(e) Road Emulsions such as 'Colas' for cold work are not at present in use in general surfacing work in the Circle, except for patch repairs.

(2) **Collection** :—The particular binder specified for the work at the particular place should be ordered for well in time to reach the site of work in correct quantity at least 7 days before the date fixed for taking it up according to programme.

III. TOOLS AND PLANTS.

(1) **Road Roller** :—This should be a powered one and is required for all surfacing work, except the primer seal work with sand blinding and is supplied by the department on loan to the Contractor free of hire charges. Heavier rollers will not be used with weaker stone-chips. All running costs and pay of driver and fireman are borne by contractor. Lubricants are supplied departmentally and value recovered from Contractor's bills. The roller must reach the site of work a day before the date fixed according to programme.

(2) **Tar and Bitumen Boiler Provided with 3′ Tank Thermometer** :—This should be at least of 200-gallon capacity and one is required for all Road Tar work including primer seal work and preferably two numbers for hot bitumen work in seal coat and reseal work. These are supplied by the department on loan free of hire charges. All running costs and pay of fireman are borne by contractor. The boilers must reach the site of work a day before the date fixed according to programme. A set of 4 spare sheets, made out of bitumen drums, will be kept with each tar-boiler to provide additional cover over the tank opening for preventing any water entering same containing binder of any kind. These are also useful for being placed under the grate and outlet pipe to prevent ashes and binders falling on the metalled width of the road if the tar boiler cannot be placed on the earthen flanks for any reason.

(3) **Reflex "Road up" Signs** :—Two numbers for each job are hired to the contractors by the department and must be available and used from the time the work is started and till the road is opened for traffic and the Road roller and tar boiler are taken off the road (including flanks).

(4) Drag-broom with necessary attachments for mix-in-place surfacing work is supplied by the department free of hire charge and there should be at least one with good brushes on the site of the work before commencing it.

(5) The following things in good order shall be arranged for by the Contractor and be at the site of work before the work is started and must be in good condition.

Name of Article.	*No. Required for Primer Seal Work.*	*No. Required for Seal and Reseal Work.*
Measuring rod equal to width to be surfaced.	2	2
Measuring rod of length which multiplied by width will give 100 square feet.	1	1
Wire brushes.	6	3
Bass brooms.	3	3
Rubber Squeezers.	–	2 (bitumen work)
Country "Soops"	3	3
Banister brushes.	6	3
Cane baskets.	4	8

Name of Article	*No. Required for Primer Seal Work.*	*No. Required for Seal and Reseal Work.*
Buckets for measuring chips ½ cubic foot size.	-	2 (Where chip spreading is required to be done by bucket measured system).
Baskets for keeping measured Chips.	-	20
Kudalis.	4	4
Buckets for measuring binders.	2	2
Pouring cans.	4	4
Special Perforated side tins.	-	4 (For mix-in-place work only).
Ladder or 2 *bullas* with clamps for loading drums on boilers.	1 Set	1 Set.
Country bamboo brooms.	10	5
String 150′ long.	2	2
Flat pointed small basuli.	4	4 (Only when perished seal is required to be removed).
Chisel and hammer.	1 Set.	1 Set.
Tar drum bung opener.	1	1
Small Spring balance with tripod stand.	1 Set.	1 Set.
Wooden straight edge batten (*patta*) 5′ long.	-	1 (For mix-in-place work).
Masons' Trowel.	-	2

For mix-in-place surfacing work on water-bound surface, the articles mentioned under primer seal work and also those mentioned under Seal and Reseal Work for mix-in-place work will be required.

IV. LABOUR.

Besides the requisite number of coolies required for the work the department will supply the following trained expert labour for proper execution of the work and will recover their wages from the Contractor's bill at specified and fixed rates.

FOR PRIMER SEAL WORK :—Boiler Man—1 (One).
Binder Spreader—4 (Four).
Blinder Spreader—1 (One).

For "2nd" SEAL & RESEAL WORK :—Boiler Man—1 For each Tar boiler used.
Binder Spreader—4.
Blinder Spreader—2.

V. ARRANGEMENT FOR TRAFFIC DURING SURFACING WORK.

(I) The wider (at least 11′ wide) flank of the road will be maintained in a fit condition to pass all traffic and where such flank does not exist, temporary diversion roads shall be provided.

(2) All obstructions, barriers, and diversions must be clearly visible from a distance by night and by day, there being a preliminary warning by Red lamp and Red flag at a distance of 300 feet from the obstruction or diversion. At the obstruction which includes Road Rollers and Tar boilers left on flanks after day's work or diversion there will be red reflex signs, red lamps placed in boxes on both ends and in the case of diversions there shall be an arrow to indicate clearly by day and by night the direction of take-off of the diversion.

(3) All diveisions other than on the road flanks will be clearly marked by whitewashed stones or other such means.

VI. WEATHER CONDITIONS.

No surfacing work is to be done in wet weather or when the road surface or blinding materials may be moist. Working with Emulsion binder only is possible with moist surface but the blinders must be perfectly dry. Clear sunny and preferably hot days are always preferable and more so for laying primer seal on water-bound surfaces, mix-in-place work and for working with straight (hot) bitumens.

VII. CLEANING AND PREPAIRING THE ROAD SURFACE.

(a) **Primer Seal Work** :—This should be taken up as soon after the reconsolidation work as possible when the road surface is dry and weather hot and sunny. The water-bound macadam surface of the road will be cleaned of all cow-dung. All topping material will be swept away. All interstices will be opened out to ½-inch to ¾-inch depth taking care not to unduly shake or dislodge any metal. Use of flat-pointed light masons "Basui" or chisels for breaking and loosening the caked blinding material within the interstices and of wire brushes, banister brushes are useful for this. Finally all dust etc. is to be blown away by means of the Country Soops and gunnies and the road surface left neat and clean with interstices between metal pieces opened.

(b) **Seal Coat and Reseal Work.**

(1) Reseal work should always be done before the previous seal coat becomes perished, brittle and dead and cracks under load. If, however, this has happened either due to abnormal delay in resealing or the original seal binder having been over-heated before application, all such perished surfacing stuff will be removed by cutting away with light blows of flat pointed light masons' basuli. all loose stuff between interstices of metal will be removed by wire brushing and the surface so freed from the old seal will be given a coat of Road Tar Nos. I or II @ 20 pounds per square foot and blinded with sand at least 3 weeks

before reseal work is to be done according to programme. In case of old abnormally hard and glazy Road Tar surfaces which may not have broken requiring removal, it is sometimes advantageous to give a tack coat of Road Tar No. I at 10-12 pounds per 100 square feet blinded with sand as in case of primer Coat work (Specified below) to prepare the surface at least a month in advance for the ⅛-inch chip of reseal carpet being satisfactorily held and retained. In such a case rate of application of binder in final resealing would be less, say 18 pounds per 100 square feet against the usual 22 pounds per 100 square feet.

(2) The surface with primer seal or previous seal, treated as above where necessary will be freed from all cow-dung, mud, dust etc. Wire brushes are useful for removing the dried cow-dung and banister brushes and country soop for sweeping and blowing away all dust etc.

VIII. Spreading The Binder.

(1) Binders should be loaded in the Tar boiler about 3 hours in case of Road tars and 5 hours in case of stright bitumens in advance of the time when they will be required for being spread over the cleaned surface and fire lighted. When these attain a temperature of about 50 degrees below the maximum temperature laid down at which they are to be applied (230 degrees for Road Tar No. I, 220 degrees for Road Tar Nos. II and III, and 350 degrees for straight bitumens like Mexaphalt 80-100 and socony 105) regulatian of fire will have to be carefully attended to so that at no time the maximum temperatures are exceeded. It is advantageous to have additional binder drums placed over the tar boiler to get partly heated to facilitate their transfer to the tar boilar later on before ¾th of the heated content is used up.

(2) Measuring buckets shall be provided with a piece of No. 12 wire or a strip of hoop iron fixed to its sides in the inside horizontally at a level upto which the hot binder will weigh exactly ½ or 1/3rd of the weight to be spread per 100 square feet. Allowance will have to be made for the quantity of binder which will remain smeared in the bucket after the measured quantity is poured into pouring cans, so that the quantity poured out would weigh correctly as required. Pouring the binder from the boiler to the can to the correct level will be supervised by the boiler man and coolies will carry these to the special binder coolies in charge of spreading. No binder should be allowed to spilt over the metalled width accidentally and to guard against it suitable sheet shall be placed under the pouring nozzle of the tar boiler.

(3) The length of the road to be surfaced will be divided in sections of such length as will give an area of 100 square feet per section by making marks on the flank near the metalled edge This is necessary for spreading of binder and blinder in correct quantity per 100 square feet as specified.

(4) The two 150′ long strings will be spread, one along each edge in parallel lines at a distance apart equal to the width of road to be sealed. Ridges of flank dust will be formed along these of about 2″-3″ height to guide the spreading coolies to spread binder correctly upto these. These are also helpful in not allowing the binder to flow beyond and giving straight edges to the sealed surface.

(5) The measured quantity of binder will be transferred to the pouring cans and the special gang coolies will pour and spread these, on the road surface starting from one side of the road and working longitudinally (not across the road), in each section of 100 square feet so that the correct quantity is put on the road as evenly as possible. Overlapping at ends of sections must be strictly guarded against. Bass-brooms are useful for spreading Road-Tars both in primer seal and 2nd seal and reseal work and Rubber squeezers for bitumen work in second seal and reseal. Much, however, depends on the quantity of binder to be spread and the prevailing atmospheric temperature at the time in using bass-broom or squeezer and whatever suits best to give the desired result should be made use of. In this way binder is spread section by section of 100 square feet each. In starting and closing a day's work both ends have to be finished oblique *i.e.* at an angle not less than 45 degrees to the length of the road.

(6) Experience shows that the following rate of application of different binders per 100 square feet for different works gives good result.

	Road Tar.	*Straight Bitumen.*
Primer seal	30 lb. (Tar I)	..
2nd Seal over Primer seal ..	28 lb. Tar II or III.	32 lb.
Reseal over sealed surface ..	22 lb. Tar II or III.	25 lb.

IX. Spreading of Blinders and Rolling.

(1) **Two methods are possible :—**

(*a*) *Bucket measured method* :—This consists in having at least 2 measuring buckets of proper size to hold ½ or ⅓ cubic foot of blinder when full or upto a certain unmistakable mark made on its inner wall and to have suitable baskets 4 or 6 times of the number of cubic feet required to be spread per 100 square feet. Half the number of baskets will be filled with one bucket measure each at a time and brought and kept alongside the section of road on which the blinder is to be spread. While these are being spread the other half numbers will be filled and brought and kept alongside the next section. After finishing the first lot, the empty baskets will be taken away to be refilled and the second lot spread and so on.

(*b*) *Stack Method* :—For this method the road is divided in sections of such length that one stack of blinder when spread on one section the quantity laid will be at the correct rate specified per 100 square feet. The blinder is brought in baskets and spreading is so regulated that one stack will be fully used up in one section.

(2) **Primer seal work (sand)** :—This may not be started until the whole length of the road which can be finished in a day's work has been laid with binder, as described under VIII above. Spreading of the sand blinder will commence from the same end from which spreading of binder had started and specified quantity will be put in and spread evenly with country brooms 3 to 3½ cubic feet of course sand usually suffices per 100 square feet.

(3) **2nd Seal and Reseal Work (Chips)** :—(*i*) While the cleaning of the road surface and heating of binder is in progress, each stack of the chips will be screened through screens (placed at 30 degrees to horizontal) of following specified size mesh stack by stack separately and what passes through will be kept separate from what is retained on the screens.

1″	Chips	to	be	screened	through	screen	with	1″	mesh.
¾″	„	„	„	„	„	„	„	¾″	„
½″	„	„	„	„	„	„	„	½″	„

(4) As soon as binder has been spread on one complete 100 square feet section and this binder spreading work goes to the next, spreading of chips will commence on the section laid with binder. The bigger chips (retained on the screens mentioned in (3 above) will be first laid uniformly. To start with, these will be laid in a strip along each edge and then will be spread in the rest by being thrown down from baskets with a swirling motion. The chips laid in strips on the edge will prevent chips from rolling away out of the width to be sealed. To ensure uniform distribution of chips and avoid crowding one over the other country bamboo brooms will be used freely. In this way whole lot of the bigger chips of a stack will be uniformly laid over each measured section of the road one by one.

(5) On one section being laid with bigger chips and while this work is going on the next section the road roller, which should be ready, will be run twice over this section.

(6) Next the smaller chips of each stack will be uniformly laid section by section so as to accommodate themselves between the bigger chips which had been rolled twice.

(7) Quantity of blinder required per 100 square feet for different works will depend on their gauge and shape and on average it may be taken as follows :—

		½″ *blinder.*	¾″ *blinder.*
Second seal on primer seal	..	5 C. ft.	6 C. ft.
Reseal over Sealed Surface	..	4.5 C. ft.	5 C. ft.

(8) Further rolling will be done as many times as required and to such an extent that the chips are all firmly embedded in the binder without being unduly crushed. Harder and bigger the size of ships the more the rolling necessary. A 6-Ton Road Roller is preferable for this work but nothing heavier than 8 tons should be used in any case.

(9) If there happens to be any finer chip dust available (which is usually the case when chips are-broken on roadside and more so in case of granulator broken chips) the same could be spread evenly up to 1½ cubic feet per hundred square feet or less as available and the work may be considered completed. Special care is necessary in finishing the two ends of the section surfaced obliquely and so as not to cause any bump. If this section joins a previously sealed length, it is necessary to lay binder and smaller grade blinder on 4′-5′ of the old surface so as to gradually merge the new surface into the old. If the section joins a water-bound macadam length besides the above, 3′-4′ of the end should be left without a second seal. In short it is necessary to join ends so as not to have a spot likely to cause bump to fast moving vehicles.

(10) If at all possible, traffic must be kept off the new work for about 24 hours from the time of completion and this is particularly useful in case of bitumen work and almost necessary for sections having sharp curves and steep gredients. If this is not done the fast moving vehicles coming to the sharp curves or steep gradients apply brakes suddenly and this tears off and removes the chips leaving bare strips which are difficult to mend.

The road should be opened to traffic, all appliances etc. removed and flanks made neat and tidy. Arrangement will be made that any binder thrown on flanks by action of traffic will be swept back (free from dust etc.) to the surfaced area for about 2 weeks. All spots found bleeding during the hot sunny days will be kept blinded with course sand fine stone-chips or gritty material as available.

IX. Mix-in-place Surfacing Work.

This method of work is suitable to re-surface a sealed surface which has generally become uneven or shows signs of corrugation or whose camber is excessive. It is also useful in surfacing water-bound macadam which was consolidated some years back and though roughish is sound in other ways having sufficient thickness of metalling to bear the loads to which it is liable to be subjected, but could not be surfaced by the ordinary method specified above.

(1) **Material:**—The binder required for the work is either a cut-back bitumen like Socofix or partly Road Tar 2 and partly Socofix. The quantity of binder and chips and the grading of latter required would depend on the extent of the defects in the road surface to be corrected. The chips instead of being of one grade as in case of simple surfacing work, have to be of 3 grades *viz.* the biggest specified for the work, about 50%: next smaller size 25%: and still smaller, say, $\frac{1}{4}$ inch to $\frac{3}{8}$ inch size 25% on average. The total quantity of chips is 60 to 75% more than for simple surfacing work.

(2) **Cleaning the Road Surface.**

(*a*) Reseal Work....Same as VII (*b*)

(*b*) Original surfacing work.

If it is to be done as single coat work, same process will apply as mentioned in VII (*a*). If it is to be done as two coat work *viz.* a primer seal in ordinary way and a seal coat by mix-in-place method, then both VII (*a*) and (*b*) will apply at proper times.

(3) **Spreading the Binder.**

(*i*) For directly spreading on the road surface whether sealed or water-bound the same method will be followed as given in VIII except that cut-backs like Socofix do not require any heating in tar boilers and are laid cold.

(*ii*) It is also necessary to lay the cut-back over chips spread on the road surface and for this the special pouring tin made of Kerosine Oil tin, with top half of one side perforated with $\frac{3}{16}$ inch to $\frac{1}{4}$ inch diametre holes, $\frac{3}{8}''$ apart and the opposite side provided with a holding handle, is to be used. Half tin full of the cut-back binder will be taken in the tin and holding it in

the hand in a tilted position the binder falling through the holes will be laid on the chips.

(iii) It is also necessary to use some of the binder by premixing with chips. For this purpose $2\frac{1}{2}$ to 3 pounds of binder will be mixed with 1 cubic foot of chips on sheets and kept ready for use. About $1\frac{1}{2}$ cubic feet of intermediate grade of chips per 100 square feet of work to be done would suffice on average.

(4) **General Procedure.**

(a) *Re-surfacing work.*

(i) Clean the road surface.

(ii) Lay 55% of total specified quantity of binder (may be Road Tar or cut-back, but not straight bitumen) on road surface as generally specified in VIII above, except that in case of cut-backs like Socofix no heating will be required. On average 20 pounds per 100 square feet should suffice.

(iii) Spread the biggest grade chips as generally specified in IX. On average 4 to 5 cubic feet of chips should suffice.

(iv) Lay cut-back such as Socofix about 30% of total specified quantity of binder over the chips by special pouring tins. On average 10 pounds per 100 square feet should suffice.

(v) After about half a furlong of the road is laid with binder and chips as mentioned above (the work should be done speedily so that if Road Tar had been used for first application it does not cool down) place drag-broom and have it dragged by coolies forward and backward loaded with two men sitting at back and centre of the frame. When this is being done the movement and coating of the chips should be kept under careful observation and at places (depressions) where the brush of the drag-broom does not touch and fails to move the chips, put in some more of chips and cover these by some cut-back binder. In course of 6-8 runs of the drag-broom on average, the chips will get $\frac{3}{4}$th coated with the binder.

(vi) Attach drag-broom to the power roller and let both work together on the surface forward and backwards, adding chips and cut-back where necessary and only just sufficient till all chips appear almost fully coated. It would be necessary to keep the drag-broom loaded by two or three persons for sometime at least.

(vii) The last run of the roller in above should be the one in which the drag-broom had moved in its front. Watch the suface and where the roller wheels do not appear to have pressed the chips due to local depression or spots being bare of chips, put in required quantity of the premixed chips kept ready for this purpose in advance. Let the roller with drag-broom run once more each way and stop and again watch and put in premixed chips where required. Repeat only just sufficient number of times till all surface appears levelled up. The 5′ wooden straight batten and 150′ long string should be helpful in checking this.

(viii) Detach drag-broom from roller. Roll twice and again watch surface and if there are any bare spots put in premixed chips sparingly taking care not to place more than required which otherwise would cause bumps. Roll once more and stop.

(ix) Spread ¼" to ⅜" chips uniformly all over. 1½ to 2 cubic feet per 100 square feet should suffice.

(x) Roll a few times. Spread chip dust if available or clean course sand one to one and a half cubic feet per 100 square feet and roll twice and thus complete the job. Try and keep traffic off the road for 36 hours or more if possible and after this open to traffic.

(b) *Surfacing roughish water-bound macadam surface.*

If this has been given a primer coat in advance, the same mathod as specified for resurfacing work will be followed.

If no primer coat has been put in, the procedure will be following :—

(i) Clean the road surface.

(ii) Lay 60% of total specified quantity of binder as mentioned in (a) (ii) above.

(iii) Same as (a) (iii) above.

(iv) Lay cut-back such as Socofix about 25 to 30% of total specified quantity of binder over the chips by special pouring tins. On average 15 pounds per 100 square feet should suffice.

(v) to (x) same as (a)-(v) to (x).

(c) Where excessive camber in the road is also to be reduced it is necessary to screen the biggest grade of chips through a suitable mesh screen to divide same in two grades. The chips retained on the screen should be used for spreading at the two edges in strips equal to about ¼th of the width of the road and the smaller chips in the middle strip equal to about ½ width of the road. After this the rest of the process will be same as given above.

PAPER No. G—39

LIGHT BITUMINOUS SURFACINGS

BY

I. A. T. SHANNON AND B. V. VAGH

I. INTRODUCTION.

In the following Paper the authors have endeavoured to clarify the present position in India in regard to light forms of bituminous surfacings which are suitable for the treatment of through roads connecting Provinces, Districts or Divisions and which are not generally meant for city streets, roads adjacent to headquarters stations, roads leading to factories, workshops or railway stations or other similar heavy duty roads. Their reasons for concentrating on light forms of construction are as follows :—

(*a*) Light forms of construction are comparatively cheap and as such are likely to meet the financial conditions governing the urgently needed general improvement of roads in India.

(*b*) The traffic distribution on roads on which light forms of construction are used is different from that of others and the milage of such roads is so vast that their study should be of considerable value to engineers and to the community.

(*c*) Light forms of construction have proved so successful in some parts of India that they merit, in view of their financial advantage, the serious attention of all road engineers

(*d*) Light forms of construction have produced such varying results at different places, under similar conditions of traffic, that there is a wide field for research and correlation of information.

(*e*) The principles involved in light forms of construction under Indian conditions of traffic appear to the authors to differ in some essentials from the principles governing these forms of construction in other countries and, if this is correct, it is desirable that the differences and their implications should be established.

This Paper is confined to light forms of construction using bitumen as a binder. This is because the data at the authors' disposal mainly relates to work with bitumen and not with other binders. Much of what they write may be considered to be applicable to work with other binders also but some, on the other hand, rests on the particular characteristics of bitumen.

II. CLASSIFICATION OF TYPES OF CONSTRUCTION CONSIDERED.

No definition has been established in India so far between light and heavy forms of surface construction and the writers have not found it easy to decide to what degree of strength of construction they should limit their

material. They suggest, however, that light forms of construction may be considered to be such as will provide a wearing surface but will not be required to take up in themselves the traffic load and impact stresses which they transmit direct to the load bearing road crust. This excludes all types of superimposed original carpets whether premixed or grouted and limits the scope to dressings which are anchored to or partly embedded in the base. It is felt that such a classification is necessary to differentiate between constructions which form part of the base and which are superimposed protective layers of varying thicknesses.

On this basis the following forms of construction will be considered:—

(1) Priming coats.

(2) One coat surface dressing.

(3) Two coat surface dressing.

(4) Light chipping carpets

(5) Retreatments.

In the large majority of cases where light surfacing is carried out, it is applied over a load bearing crust of water-bound macadam constructed with granite, trap or brick ballast. It is suggested that it would not be incorrect to consider the light surface construction really as part and parcel of the macadam construction whether it is applied as such or at some later date as an improvement. The authors would particularly like to stress this point as they will further on make certain suggestions regarding the combination of surfacing work with macadam construction.

III. DETAILS OF TYPES OF CONSTRUCTION.

A. PRIMING COATS.

1. **General**:—Priming coats have not been adopted to any great extent in India but they are being increasingly used in certain other countries and it will probably be of value to discuss their place in the field of light surfacings.

Priming coats are applied over water-bound macadam prior to surface treatment and the advantages that are generally claimed for them are:—

(1) That they increase the stability of the water-bound macadam by virtue of the binding properties of the primer used, particularly in so far as they stabilise the fines present in the top portion of the water-bound macadam.

(2) That they form an insulating layer underneath the surface treatment which will block the rise of sub-soil water and thereby prevent a tendency towards peeling off of the surface construction due to upward movement of sub-soil water through the macadam construction.

(3) That they provide a certain amount of free binder which will be available to stabilise loose particles formed by the attrition of the water-bound macadam under traffic.

(4) That they "prime" the stones to be surface painted, thereby ensuring that maximum adhesion of the subsequent surface treatment is obtained.

In regard to these claims the authors are of the following opinion :—

(1) The ability of priming coats to increase the stability of water-bound macadam seems to the writers to be governed by two factors, *viz.* (*a*) the capacity of the earth blindage to absorb the primer and (*b*) adhesiveness of the primer. It should not be assumed in any case that the use of a priming coat will be a cure for bad consolidation of the water-bound macadam itself and it is far better to have a well constructed water-bound macadam with no priming coat than a poorly constructed water-bound macadam with a priming coat.

(2) The function of a priming coat as an insulator against the upward rise of sub-soil water is of obvious value in places where the water table is very near the surface level of the road.

(3) The ability of a priming coat to provide free binder that will be available to stabilise fine particles formed by the attrition of the macadam under traffic seems to the authors to be very doubtful. Primers must of necessity have low viscosities to enable them to penetrate and carry out their stabilising functions. It seems probable, therefore, that when a priming material is applied to water-bound macadam it will penetrate until it combines with fines (and adheres to the stones) up to the maximum extent of its absorptive and adhesive capabilities. If this is so, there will be no free binder available for other works, on the other hand if any excess is applied it may soften the binder in the main treatment.

(4) The ability of a primer to "prime" the surface of the stone to be subsequently treated with surfacing is fairly well established and this function of a primer is of real value when surface painting has to be carried out on water-bound macadam made of stone such as certain varieties of quartz, hard laterite, etc. which have a poor affinity for bitumen. For good quality stone, judging by results, no priming seems to be necessary if the stone heads are clean.

2. **Types of Primer:**—Primers may vary considerably in composition but the salient features are similar. A good primer should have a sufficiently low viscosity at application temperature to enable it to penetrate well into the macadam. This viscosity should be combined with a stable composition and it is undesirable that for priming purposes a material of low viscosity should be obtained by the use of large quantities of solvent in combination with hard bitumen. If this is done rapid volatilisation of the solvent will result in the deposited bitumen setting without carrying out its absorptive function. A good primer should be either a heavy asphaltic oil or a blend of soft bitumen with a heavy oil.

3. **Rate of Application:**—The use of a primer will, in all circumstances, be governed by cost; it is obviously not economical to use large quantities of primer when the cost of doing so will increase the cost of the surface treatment to a point where an alternative and stronger type of construction could be carried out. It will probably be sufficient to employ a primer at from 15 pounds to 25 pounds per 100 square feet according to the condition of the water-bound macadam and the function that the primer is particularly required to carry out, *e. g.*, priming to increase the adhesion of the subsequent wearing coat will require less material than priming to increase the stability of the water-bound macadam. It is sometimes claimed that the use of a primer will allow a considerable saving in the amount of binder used in the subsequent surface treatment. While a small saving can

undoubtedly be made, the authors are of the opinion that this aspect should not be over-stressed, since the functions of a primer and a wearing coat are so materially different that one cannot take the place of the other.

4. **Blindage:**—The authors are of the opinion that primers should not be blinded except under certain very special circumstances which will be detailed below.

Generally speaking, it is obvious that if a primer is to carry out the functions detailed above, it will not have sufficient adhesive material in its composition to enable it to hold a layer of blindage as well as to carry out its proper penetrating and stabilising function. This is not the only disadvantage of blinding a primer, however, and a more important one, in the authors' opinion, is that the use of blindage, even of sand, will prevent the blindage of the following surface treatments from keying properly into the surface voids of the water-bound macadam.

The circumstances under which a primer might be blinded are when it is desired to open the primed water-bound macadam to traffic in order to ascertain and remedy any defects in the water-bound macadam before applying the final seal A very light blinding is recommended here. In this connection and in connection with primers generally, the following extracts from the Third Report of the Standing Committee on Rural Roads (1937-38) in New Zealand published in the Proceedings of the New Zealand Institution of Engineers may be of interest.

"One Coat Sealing".—The use of a priming coat which penetrates into the crust gives a true bond between the crust and the sealing and in consequence a part of the crust becomes incorporated with the sealing coat. This results in obtaining a satisfactory sealed surface with one coat of actual sealing, and it is now considered unnecessary with moderate traffic density to apply a further sealing coat until considerable wear has taken place.

It is desirable that a priming coat should be proved under traffic conditions before the sealing coat is applied, and adequate repairs should be carried out as any defect in the surface becomes apparent. It is wiser to effect repairs prior to the application of the sealing than allow the sealing also to fail. On the other hand if it is positively certain that the crust surface when primed is in a fit condition the sealing coat may be applied when complete absorption of the priming coat has taken place".

Under Indian traffic conditions it is safer not to open a primed surface to traffic at all since the iron tyres of bullock-cart will tend to remove the thin coating of stone-heads thus defeating one of the objects of primers.

B. SURFACE DRESSING.

1. **General:**—The method of forming an improved road surface by dressing water-bound macadam with an application of bitumen has now been in vogue for very many years and in Europe for a quarter of a century at least. The treatment was first employed purely as a surface protection for the water-bound macadam and the basic principle followed, when the introduction of mechanical vehicles resulted in this form of surfacing being developed, was that the binder was applied to act as a seal over the water-bound macadam to prevent pneumatic-tyred wheels

from sucking out the fines from the macadam and so destroying its stability. The earliest surface dressings were not blinded and it was only when it was discovered that the binders which gave the best results on account of their adhesive and lasting properties were, on account of their very adhesiveness, also liable to stick to the tyres of vehicles using the surface that "blindage" was resorted to. In its first use, blindage was solely intended as a siccative to prevent the binder from sticking to traffic wheels. In course of time, however, it became apparent that the blindage itself played an important part in the success of surface dressing and in Europe the convention has now completely changed from the application of a binder blinded with a siccative to the application of a wearing course of mineral aggregate bound together and to the road with a bitumen binder. In India the conditions are far more severe than they are in Europe and with traffic loads in the region of 2000 pounds per square inch, as compared with 25 to 50 pounds per square inch in Europe, the parts that the components of surface dressings are called upon to play are much more complex and more difficult to understand.

2. **One coat Surface Dressing:**—*(a) Specification.* A broad specification for this form of surfacing when applied over water-bound macadam (primed or unprimed) is as follows:

(1) The road shall be thoroughly cleaned.

(2) Bitumen shall be applied to the surface at a rate of from 35 to 45 pounds per 100 square feet.

(3) Chippings or shingle shall be applied over the bitumen at a rate of from 4 to 6 cubic feet per 100 square feet.

(4) The chippings shall be thoroughly rolled with a power roller of 4 to 8 tons weight.

There are many variables in the above outline specification which, in the main, relate to the following:

(1) Type of bitumen binder.

(2) Its quantity.

(3) Type of aggregate.

(4) Its quantity.

These will be discussed below.

(b) Types of Binder. Bitumen binders may be

Straight Run Bitumens.

Cut-back Bitumens.

Bitumen Emulsions.

Straight Run Bitumens suitable for surface dressing vary from semi-soft to soft grades in the following standard penetration:—30-40 penetration, 80-100 penetration, 130-150 penetration and 180-200 penetration. In surface dressing work there is a very gradual but inevitable tendency for the bitumen to harden by oxidisation in course of time and if re-treatment is not carried out at a suitable stage of the treatment's life, the binder may eventually harden to such an extent that it may lose its adhesiveness.

Bitumen is a very homogeneous material and this hardening process is only very gradual. The authors are, however, of the opinion that it is advisable to reduce the effect of this process by initially adopting as soft a grade of bitumen as may be used without serious danger of the surface pushing or waving. A few engineers prefer 30-40 penetration bitumen because its hardness makes it comparatively foolproof in that an excess of application may not lead to "bleeding" so easily. The most widely used grade, however, is 80-100 penetration bitumen, while the softer grades are now being tried out by engineers in some parts of the country.

Cut-back Bitumens—These binders have not been used very much in India for single coat surface dressing work. The advantage which they possess of high covering capacity is probably offset by the smaller quantity of covering material which the application will hold and the higher cost probably negatives the advantage of their lower application temperatures. They have, however, the advantage of a certain priming effect and are perhaps indicated for surfacing water-bound macadam that is difficult to clean or made of a soft stone, although in such cases pre-treatment with a primer may be preferable In general, cut-backs may be said to be more useful in retreatment than in first construction.

Emulsions for surface dressing normally have a bitumen content of not more than 60 percent For initial treatment of water-bound a fairly heavy application of binder is desirable and, therefore, for one coat work emulsions are usually ruled out on grounds of cost Good results have been obtained, however, with heavy application and they have the advantages of requiring no heating and of being capable of being used with damp aggregate. In places where it is undesirable to use heating plant or where very rapid construction is required, their use is indicated and very many miles of excellent surfaces have been made by surface dressing with emulsions in the North-West Frontier Province.

(c) *Quantities of Binder.* The bitumen binder is required to carry out the following functions –

1. To adhere to the water-bound macadam (primed or unprimed) road.
2. To absorb the cover material and,

   Under iron-tyred traffic.
3. Subsequently to take up fragments formed by the crushing of the stone chippings under iron tyres

The last function, in the opinion of the authors, is probably the most important consideration in India in deciding what quantity of binder should be used in surface treatments It is not possible to lay down hard and fast rules to cover all cases but the authors are of the opinion that, generally speaking, the following quantities will give the best results :—

1. *Where there is no iron-tyred traffic* —33 to 35 pounds of binder will hold 4 to 5 cubic feet of chippings and give an excellent surface for pneumatic tyres
2. *Where there is iron-tyred traffic and when chippings are prone to crush.* 40 to 50 pounds of binder will hold about 5 to 6 cubic feet of chippings and will take up the crushed fragments thus forming a resilient surface resistant to iron-tyred traffic.

3. *Where there is iron-tyred traffic and the chippings are very hard and do not crush.*—33 to 35 pounds of bitumen will hold 4 to 5 cubic feet of chippings but *under these particular circumstances a pre-coated chipping carpet is to be preferred.*

(*d*) *Types of Blindage.*—Granite, trap, basalt and other igneous rocks are widely available in India and chippings broken from these rocks are generally speaking suitable for blinding surface dressing. Exception must be taken to stone which, under iron tyres, crushes to powder. When chippings break into fragments the surface area, which has to be covered by the binder holding the chippings, becomes appreciably greater. Experience shows that by using the correct amount of binder, based on knowledge of the behaviour of the particular chippings under traffic, a stable surface can be obtained which contains the percentage of the original chippings which remain whole having been embedded in the surface voids of the macadam plus the broken fragments of the chippings which have crushed, bound by the binder. If, however, the stone is of such a nature that it breaks down to *powder* rather than into fragments, the surface area on which the bitumen is required to work is increased to such an extent that the bitumen becomes "over mineralised" and "dead", and therefore fails. In the opinion of the authors, therefore, chippings made from stone which crush into powder should never be used. Good results are often obtained, however, with chippings which crush into fragments provided an excess of binder is present. It would be logical to expect that the harder the stone chippings the better will be the results blained from using them, but in the opinion of the authors this has not been borne out in practice, and the very best results in surface drestnig have been obtained where a certain propoition of the chippings have crushed resulting in the formation of a thin resilient surface layer which is resistant to the abrasive effect of iron tyres Results have been particularly good where the uncrushed portion of the chippings have wedged themselves into the surface interstices of the water-bound macadam.

Siz e of Chippings.—Good results appear to have been obtained at different places with different sizes of chippings, and the authors are of the opinion that this question is one for decision by local experience rather than by any hard and fast rules. It may, however, be said that the size should be such as can be conveniently accommodated in the surface voids of the water-bound macadam. Thus if the stone used in water-binding is over 2 inches in gauge, a size of 5/8 inch to 3/4 inch is indicated for surface treatment; if about $1\frac{1}{2}$-inch gauge, a size of $\frac{1}{2}$ inch to 5/8 inch is indicated In general $\frac{1}{2}$ inch to $\frac{3}{4}$ inch chippings are desirable

There are some binders which, on account of their susceptibility to heat, are sometimes found to "bleed" during the hot weather, particularly if they are used at all heavily. The question of the size of the blindage in relation to "bleeding" is an interesting one and one of the authors recently had an opportunity to test the often expressed theory that small chippings or graded chippings with their greater surface area then larger chippings would tend to minimise "bleeding". In practice at a number of trials it was found that the reverse is the case and that the smaller chippings and the graded chippings became "flooded" with the binder, which did not happen in the case of larger chippings.

Shingle.—Water worn river or *nallah* shingle is sometimes used for blinding surface dressing. On account of its lack of angularity it cannot key so well into the water-bound macadam base as chippings do; nor can it,

in such cases where the surface dressing forms a definite carpet, possess the stability of a carpet made from angular stones. Good results have, however, undoubtedly been achieved with shingle, particularly in cases where the binder is so regulated that there is no excess to aggravate the movement of the unstable rounded stones.

(e) Quantities of Blindage.—The normal limits should be from 4 to 6 cubic feet per 100 square feet the exact quantity being regulated (1) by the nature of traffic and (2) by the quality of the stone. For the same quantity of binder, pneumatic-tyred traffic will hold more chippings. For the same quantity of chippings, a softer stone requires more binder.

3. **Multiple coat surface dressing**:—This term means the use of more than one coat, but normally the work falling under this head consists of two coats only. Two varieties in this class are generally used (1) Surface-dressing in two coats and (2) Heavy type surface-dressing which is also in two coats.

(a) Two coat surface dressing—Normal. A broad specification for this form of surfacing is as follows

(1) The road shall be thoroughly cleaned.

(2) The first coat of bitumen shall be applied at a rate of 35 to 40 pounds of bitumen per 100 square feet.

(3) Chippings or shingle shall be applied over the bitumen at a rate of 5 to 6 cubic feet per 100 square feet

(4) The chippings shall be thoroughly rolled with a power roller of 4 to 8 tons weight.

(5) The second application of bitumen shall be made at a rate of 25 to 30 pounds per 100 square feet

(6) Fine chippings or shingle shall be applied at a rate of 3 to 4 cubic feet per 100 square feet

(7) Chippings or shingle shall again be thoroughly rolled with a power roller of 4 to 8 tons weight.

The authors particularly wish to draw attention to this specification which they feel is often specified on the grounds that two coats will be better than one. They are of the opinion that it is not a sound method of surfacing for roads which carry any appreciable quantity of iron-tyred traffic and, in the case of surface dressing, the axiom that a two-coat treatment would naturally be stronger than one-coat does not seem to hold good. The reason for this seems to be that the extra quantity of binder and aggregate used alters the form of the construction from that of "embedded chippings with a wearing surface either of these chippings or of their crushed fragments" such as is produced by normal single coat surface dressing to that of an unstable type of thin carpet in which surplus binder tends to act as a lubricant preventing the bottom layer of chippings from bedding firmly into the water-bound macadam. This construction on account of its lack of stability is insufficiently strong to take up the stresses set up by iron-tyred traffic. This view of the authors may sound somewhat heretical but the opinion has been strengthened recently when inspecting a trial carried out in the Central Provinces where single coat surface dressing is actually standing up

better under iron-tyred traffic than adjacent stretches of two-coat surface dressing laid under identical conditions and carrying the same traffic.

(b) Two-coat surface dressing—Heavy. A specification which has been adopted in a few cases is as follows :—

(1) The road shall be thoroughly cleaned.

(2) A first coat of bitumen shall be applied to the surface at a rate of 20 to 25 pounds per 100 square feet.

(3) Large sized chippings or shingle ($\frac{3}{4}$-inch to 1-inch gauge) shall be applied over the bitumen at a rate of approximately 8 cubic feet per 100 square feet.

(4) The stones should be thoroughly rolled with a power roller of not less than 10 tons weight.

(5) A second coat of bitumen shall be applied at a rate of 30 to 40 pounds per 100 square feet.

(6) Chippings or shingle ($\frac{1}{2}$-inch to $\frac{5}{8}$-inch gauge) shall be applied over the bitumen at a rate of from 4 to 5 cubic feet per 100 square feet.

(7) Chippings should be thoroughly rolled with a power roller of not less than 10 tons weight.

This differs from the normal type of two-coat surface dressing in that the first application of bitumen is a light one which really anchors a layer of fairly heavy stone on to the road. The second application of bitumen, which is a heavier one, partly coats the first layer of stone and particularly anchors the second application of chippings which are applied so as to fill the interstices in the first coat of stone. This might perhaps be considered as a very light form of grout or built up carpet. In the authors' opinion it has an advantage over the normal two-coat surface dressing type detailed above, in that while it admittedly forms a type of carpet, the carpet formed will be both thicker and more stable for a similar quantity of binder than that formed by two-coat surface dressing. The drawback of this type of construction is that it is difficult to obtain a uniform surface.

C. Light Chipping Carpets.

1 General :—The "Premix" method of work has been widely used for heavy construction in India during the last few years and following the adaptation of this method of work to light carpets in England and other countries it is now being developed for light chipping carpets in this country also. The specification calls for a primer in the case of surfacing over water-bound macadam and a tack coat in the case of surfacing over a previously treated road. The carpet usually consists of $\frac{1}{4}$-inch to $\frac{3}{4}$-inch chippings coated with sufficient binder to give a bitumen content of from 3 to 4 pounds per cubic foot of chippings. It is laid to a thickness of 1 inch to $1\frac{1}{2}$ inches loose. In some cases a light dressing of stone dust is applied to the surface after final rolling. A broad specification is as follows :—

(1) The existing road shall be thoroughly cleaned of all loose dirt, dust, caked mud, etc..

(2) A Priming coat or Tack Coat of either a suitable priming bitumen, a cut-back bitumen or an emulsion shall be applied at a rate of from 15 to 20 pounds per 100 square feet.

(3) Hard stone chippings, ¾-inch to ½-inch gauge, according to the designed thickness, shall be precoated with cut-back bitumen or a premixing emulsion at a rate of 3 to 4 pounds of bitumen per cubic foot of chippings

(4) 8 to 12 cubic feet of these precoated chippings shall be evenly applied per 100 square feet of road surface.

(5) Consolidation shall be carried out with a roller of 8 to 10 tons weight.

(6) The road may either be opened to traffic immediately or closed for a short period according to the type of the binder used and the weather conditions.

(7) After the road has been under traffic for some time a liquid seal coat may be applied if traffic warrants this.

2. **Types of Binder** :—To ensure easy mixing the binder used for this work should be either a Cut-back Bitumen or an Emulsion. In either case it should be of a grade which will coat the chippings with an even and thin film of Bitumen. The cut-back may be either for hot or cold application. The selection of the binder will depend upon local conditions; cold application cut-backs and emulsions are simpler to operate but they are more expensive, and hot application cut-backs, although requiring plant for heating are cheaper both in initial cost and, normally, in the final cost of the construction Special cut-backs are now available which may be heated in their drums or in very light heating plant and which have high covering capacities.

3. **Types of Aggregate** :—It is, in the authors' opinion absolutely essential that if this construction is adopted for surfacing roads carrying preponderance of iron-tyred traffic, the chippings used shall be of a hard variety such as will not crush under the iron tyres. The reason for this is that the very essence of this type of construction is the provision of a stable carpet composed of chippings bound together by the correct amount of binder. The correct amount of binder is the minimum amount, as any surplus binder would act as a lubricant between the chippings and allow of distortion of the surface which is important since this form of construction has a thickness of say 1¼ inches and any movement in the surface would seriously affect its riding qualities. The minimum quantity of bitumen required to coat the stones and bind them together must, therefore, be used and this minimum quantity allows of no excess which might serve to take up the fragments produced by the crushing of chippings under iron tyres, so chippings which will crush should not be used. In spite of this precaution, it may be difficult under certain traffic conditions completely to safeguard the crushing of the chippings. As a further precaution, therefore, it is an advantage to lay such a carpet on an open water-bound base so that it can be largely embedded in the base thus minimising the chances of the chippings getting crushed between the base and the traffic.

4. **Size of Aggregate** :—It seems to be a generally accepted principle that the maximum size of the chippings shall not be larger than two-thirds of the consolidated thickness of the carpet and shall comprise about 60 per cent of the whole.

Graded chippings give greater stability but require skilled laying as, if they are not carefully raked, there is a tendency for the fines to be segregated by the rakers. A method sometimes adopted to obtain extra stability and a close surface is to lay the carpet initially with large size of chippings and partially consolidate it. The fine chippings should then be added to fill the surface voids and final consolidation carried out.

D. Surface Dressing Versus Light Chipping Carpets.

1. **Surface Dressing in General :**—Of the various types of light bituminous construction which have been carried out in India, single coat surface dressing has, in the opinion of the authors, undoubtedly given best results, and where the combination of the correct amount of binder with a suitable aggregate has been arrived at this inexpensive type of treatment has been found to stand up to surprisingly heavy traffic notably on many miles of roads in the United Provinces where the combination of chippings made from a stone which will crush into hard fragments and a heavy application of binder has been particularly successful. The results achieved have been so successful and economical that the authors consider that in other districts where the aggregates available are different, experiments should be carried out to find which of the locally available aggregate will give good results and with what quantity of binder.

2. **Surface Dressing compared with Light Chipping Carpets:**—From a comparison of quantities of materials used, it will be seen that a chipping carpet requires more materials than a single coat of surface dressing and less than a double coat and that is a fair index of its cost which usually should not exceed that of two-coat painting.

When designing a light bituminous treatment, therefore, an engineer has the choice of these two different types of light treatments at much the same cost. The authors would like to suggest that the following factors should be considered when coming to a decision as to which type of construction to adopt :—

1. For pneumatic-tyred traffic a premix chipping carpet presents a more even and skid-proof surface than can be obtained with surface dressing, also it will last longer and require less maintenance.
2. By using a premix chipping carpet it is possible to correct unevenness of the existing base which cannot be done with surface dressing. In fact a chipping carpet can easily be laid upon a slightly worn-out water-bound base thus saving the cost of reconstruction.
3. That surface painting is to be preferred to chipping carpets if the iron-tyred traffic is heavy and the chippings of a type that will crush.

E. Retreatments.

1. **General:**—Light construction, such as surface dressing, cannot last for ever and there must come a time when the engineer in charge of a road has to decide whether he will prolong the life of the surface by re-treatment or whether he will surrender the salvage value of the surface and allow it to wear to destruction with the consequent necessity of reconstruction.

It may occasionally happen that a type of surface is provided which is found to be insufficiently strong for the traffic using the road possibly due to an increase in traffic subsequent to the original surfacing and in these cases reconstruction with a stronger form of construction will probably be better than re-treatment. Under normal circumstances, however, it should be possible to prolong the life of an original treatment for very many years by proper maintenance and by retreatment when necessary. There are today roads in India which were first treated with a single coat of bitumen and chippings as long as 10 years ago and which have been maintained in this manner.

Maintenance consists of the continual and vigilant inspection of the surface for local flaws and damage and in the rapid repair of such weaknesses. Retreatment is a larger matter and consists of the renewal of the surface when it shows signs of general deterioration either due to the hardening of the binder or to general wear by traffic. In either case it is essential to carry out the remedial treatment before the surface has deteriorated to such a degree that the success of retreatment is doubtful.

There are a number of different methods available for retreatment and before detailing these the authors would like to mention the use of retreatments to form what is in reality multiple coat work. In section III, B 3 (a) the authors have suggested that two-coat work is an unsatisfactory form of work on account of the excess of binder and the lack of stability of the superimposed carpet formed by this method of construction. There are cases, however, where a second and a third coat, applied at intervals of from six months to a year after the initial coat, have built up a stronger surface than was obtained with the original coat, and multiple treatment in this form appears to give satisfactory results.

Retreatments may be broadly grouped into three classes :—

(1) Complete retreatment.

(2) Thin re-seals.

(3) Enlivening treatment.

2. Complete Retreatment:—These treatments may be similar to the initial treatment. On account of the absence of surface interstices in the surface to be retreated, however, there will not be the same possibility of the chippings wedging into the surface voids, and on that account smaller chippings are usually used as the surface to be treated is much smoother than water-bound macadam. As the blindage is usually smaller a less quantity of bitumen is also normally employed. A suitable specification would be as follows :—

(1) The road shall be thorougly cleaned.

(2) Bitumen shall be applied to the surface at a rate of 25 to 30 pounds per 100 square feet.

(3) Small gauge chippings shall be applied to the bitumen at a rate of 3 to 4 cubic feet per 100 square feet.

(4) The chippings shall be rolled with a suitable roller.

3. Thin Re-seals:—These are applied when the surface is not allowed to wear to the extent that full retreatment is necessary and are intended to replace not the entire treatment but only the part which has worn out. It was mentioned under Section III. B 2 (d) above that part of the chippings

in the first treatment get embedded in the water-bound macadam and part get crushed to form a thin resilient seal. It is this seal which it is intended to renew. The treatment usually consists of a very light application of binder with a high covering capacity such as an emulsion or a cut-back bitumen, blinded with sand. A suitable specification would be as follows :—

(1) The road should be thoroughly cleaned.

(2) Cut-back bitumen or emulsion should be applied at a rate of 15 to 25 pounds per 100 square feet.

(3) Sand should be applied on the surface at a rate of 2 cubic feet per 100 square feet.

(4) After a period of a few days the surplus sand not absorbed by the binder shall be removed.

4. **Enlivening Treatments:**—The purpose of an enlivening treatment is to prolong the life of a surface which shows signs of possible failure owing to the hardening of the binder. The essential point in such a treatment is that the material used shall have the power of soaking into the surface and combining with the binder of which it is composed. Cut-back bitumens made with heavy solvent having slow evaporating but high penetrating properties are most suitable for this kind of work. Blindage is only used if it is needed as a siccative owing to incomplete absorption of the treatment. A suitable specification would be as follows :—

(1) The road shall be thoroughly cleaned.

(2) Suitable Road Oil or cut-back bitumen with high penetrating properties shall be applied at a rate of 10 to 20 pounds per 100 square feet. It shall be allowed to soak into the surface for a period of 48 hours.

(3) After 48 hours the road should be lightly blinded with sand being opened to traffic.

(4) After a period of a few days surplus sand should be removed.

5. **Scope of Retreatments.**—A decision as to which of the three methods of retreatment of light surface discussed above should be used in particular cases will naturally depend on local conditions. However, as a general rule it may be said that the enlivening treatments should generally be used on residential roads, footpaths, etc. where traffic is very light. The other two treatments should be on other roads, the selection being decided by the comparative life of each treatment and its cost. Generally speaking, from the point of view of availability of funds, it is more convenient to adopt a lighter construction since it can be more easily afforded. From this point of view thin re-seals are more convenient and have to be preferred to complete retreatment except where traffic is heavy.

IV. CONCLUSIONS AND SUGGESTIONS.

Summarising what they have written under various sections the authors would like to submit the following conclusions :—

A. General.

1. That the forms of surfacings discussed in this Paper have been proved to be capable of standing up to the normal mixed traffic operating on through roads in India, made up of Bullock Carts, Motors and Buses.

2. That although the requirements of motor and cart traffic are not the same it is possible to build these constructions to suit both.

3. That single coat surface dressing is the best form of construction under mixed traffic if the correct quantity of bitumen is used to suit the quality of chippings available.

4. That the two-coats-together type is not generally so satisfactory and where it is felt that traffic requires more than one coat it is advisable to apply the subsequent coat after an interval.

5. A chipping carpet is to be preferred where the chippings are of good quality and the water-bound macadam can be brushed to expose the surface voids.

B. SELECTION OF TYPE OF CONSTRUCTION

1. The basic consideration in selecting the most suitable form of construction is the quality of chippings.

2. If they are of good hard stone like trap then the alternatives are (*a*) a chipping carpet and (*b*) single coat surface dressing.

Chipping carpet should be used if it is not intended to re-metal the base; surface dressing should be used if it is intended to re-metal it.

3. If the chippings are not of good quality stone then only surface dressing should be carried out.

C. NOTES ON SPECIFICATIONS.

1. **Water-bound Macadam** :—A light surfacing is really a part of the original water-bound macadam. Hence the latter must be carefully constructed to obtain the best results from the former. The main points in its construction are (1) the use of the maximum quantity of metal, (2) minimum blindage and (3) sufficient wet rolling to fix the metal so thoroughly that it can stand very vigorous brushing. Unfortunately many roads are constructed without due regard to these principles.

2. **Primers** :—Primers are useful when the metal in the macadam has no great affinity for bitumen, possibly also where the earth blindage has a certain amount of porosity. A primer should be very fluid at application temperature, should be capable of being subsequently absorbed by the surface and should be applied between 14 to 25 pounds per 100 square feet. *Primers should not be blinded.*

3. **Bitumen for Main Treatment** :—(*a*) For surface dressing water-bound macadam a straight run bitumen is to be generally preferred. It should be as soft as possible. Suggested grades are 80—100, 130—150 and 180—200 penetrations.

(*b*) In surface dressing (one coat) chippings of hard stone like trap will require about 6 pounds of bitumen 80—100 penetrations per cubic foot, chippings not so hard as trap will require about 8 pounds. In the absence of any proof at present of the value of laboratory tests on different varieties of chippings the only suggestion the authors can make is to experiment with these quantities with local aggregates and adjust the correct amount according to experience.

(c) For Chipping Carpets cut-backs and premixing emulsions are to be preferred to straight run bitumens. Cut-backs with high covering capacities, which will deposit thin films of bitumen, are to be preferred.

(d) For premix, quantities may vary from 3 to 4 pounds of Bitumen per cubic foot of chippings according to the softness or hardness of the basic bitumen and the grading of chippings.

(e) For re-treatments cut-backs have special advantage.

4. **Aggregates** :—(a) The fact that chippings may crush to fragments under iron-tyred traffic does not preclude their use in successful surface dressing work.

(b) The normal quantity found useful is 5 to 6 cubic feet per 100 square feet in surface dressing and 8 to 10 cubic feet per 100 square feet in premix.

(c) For chipping carpet work hard stone chippings are necessary.

(d) Chippings which crush to powder should never be used for any type of construction.

5. **Retreatments** :—(a) More frequent renewals of a light treatment are preferable to less frequent renewals of heavy coats, since (1) they prevent a tendency towards oxidisation of the original surface and (2) can be more easily financed from maintenance grants on account of their comparative cheapness.

(b) The possibilities of further reducing the cost of such renewals by the use of cut-backs from soft bitumens should be investigated. If it be feasible to produce a quick setting hot cut-back capable of re-sealing a surface at, say, not more than 10 pounds per 100 square feet, then a retreatment should not cost more than Rs. 500/- per mile, 10 feet wide. In that case even if it becomes necessary to re-seal a surface every year it should be possible to afford its cost from maintenance grants.

(c) Light renewals should be blinded with sand and only rolled lightly or not at all.

V. BITUMEN CHIPPED MACADAM.

It is the opinion of the authors that the best results with surface dressing have been obtained when the treatment combines intimately with the water-bound macadam base, both by the adhesion of the binder to the macadam and by a portion of the chippings wedging into the surface interstices of the macadam.

If this is correct the implication would appear to be interesting and the question arises, would it not be possible to improve, simplify and cheapen light surfacing construction by including the provision of the surface as part and parcel of the water-bound construction? Could this not be done by embedding coated chippings in the surface of the macadam during construction and keeping the surface intact by periodical but economical re-treatment?

This should simplify the procedure greatly by reducing the number of operations. There would also be other advantages; water-bound macadam is not really a simple form of construction. It necessitates the scarifying

of the base which may destroy a solidarity which has been acquired by many years of consolidation under traffic. The construction requires the use of large quantities of water which in several provinces means short working seasons and a long wait between monsoons. There is not always proper control of this water which may be either too little or too much, which fact in its turn may necessitate adjustments either in rolling or blinding. The specification which the authors now suggest should be at any rate investigated, will do away with these disadvantages. It will also do away with the use of earth which is at present widely used for blinding. This use of earth is a disadvantage. It generally has to be taken from the nearest borrow pits and its quality cannot be controlled. Finally, by combining light surfacing with water-bound construction the brushing of the water-bound macadam is obviated which should be a step in the right direction because brushing, as necessitated at present, sometimes tends to weaken the macadam

Even assuming that all these defects are normally minimised by careful workmanship still the earth in water-bound macadam ,cannot impart much stability to it or offer any resistance to displacement under traffic, because a lump of earth has no "body" of its own which cannot be deformed. Therefore, the only stability we can obtain from such a construction is that derived from the interlocking of its stone for which all the various stages of the operation of water-binding as at present carried out may not be absolutely necessary.

We have proof of this fact in the construction of a full grout. Here it is not necessary to scarify the existing road. The metal is laid straight over it after brushing the surface and its open texture has been found to be sufficient to give the new metal a grip. The grout is applied after an initial rolling and is followed by a layer of chippings which are rolled light. This is followed by a seal coat. Examining this construction it will be seen that the extra stability of the grout over water-bound macadam is essentially and entirely due to two things, (1) a coat of bitumen and (2) the wedging of the chippings into the metal. Why not combine the two principles and put coated chippings in a layer of loose metal ? True the bitumen so used will be much less than in a grout but so will be the traffic, since we are not considering heavy trafficked roads but roads where light construction is sufficient and, therefore, the depth and strength of construction and the quantity of bitumen necessary for this need not be so great.

After seeing very many miles of surface dressed roads it seems to the authors that in cases where it is necessary to water-bind a road and then to surface it, a specification on the lines discussed above, which the authors feel may be aptly termed "Bitumen Chipped Macadam", should prove workable and economical. A specification is suggested below and the authors invite discussion on it. They would emphasize that this recommendation is based at present largely on theory and is provisional and at present is intended to be confined to work where good hard chippings are available. Later on it might be possible to devise a specification for other qualities of stones on the basis of entirely embedded chippings with a liquid seal.

A Provisional Specification for Bitumen-chipped Macadam.

1. The existing water-bound macadam is brushed clean and potholes, if any, are filled in with clean new metal after cutting them square. The new metal is well rammed but neither watered nor blinded.

2. Longitudinal trenches are cut one on each side of the road about one foot wide and two inches deep and are brushed clean. The trenches are filled in with a layer of 1-inch to $1\frac{1}{2}$-inch metal spread $2\frac{1}{2}$-inch thick loose and thoroughly hand-rammed.

3. A layer of clean dry metal, trap or other hard stone, 1-inch to $1\frac{1}{2}$-inch gauge is spread uniformly on the entire surface to a thickness of $2\frac{1}{2}$ inches and is thoroughly rolled with an 8 to 10-ton power roller. When the metal shows least movement rolling is stopped.

4. A light application of cut-back bitumen is applied to the surface of the dry metal with pouring can as far as possible uniformly at 20 to 25 pounds per 100 square feet.

5. A layer of premixed chippings of hard stone $\frac{1}{2}$ inch to $\frac{1}{4}$ inch gauge, coated with cut-back bitumen at from 3 to $3\frac{1}{2}$ pounds per cubic foot is spread uniformly over the entire surface to a thickness of 1 inch loose. About 8 cubic feet are normally required per 100 square feet.

6. The coated chippings are rolled thoroughly with a 6 to 8-ton power roller until there is no movement.

7. The metal excavated from the side trenches is screened and used for packing the road on both sides to a depth of about 4 to 5 inches and width of about 3 to 4 inches. Then the earth berms are raised, watered and rolled till they are firm. The road is then opened to traffic.

The points in favour of the above suggested specification have been mentioned earlier in this section. There is one further advantage, however, and that is that the specification should have a great adaptability to large scale work. From this point of view the specification has two points particularly in its favour.

These are simplicity and the fact that it can be carried out without expensive plant—two main considerations which, next to financial stringency, seem to be holding back road work in India. Experience has so far shown that so long as a work is confined to methods necessitating the use of straight bitumens or heavy cut-backs such as are used in heavy premix construction, premix cannot be carried out without the use of boilers and power mixers. Experimental work has shown, however, that a cut-back bitumen can be produced that will allow of light premix work, such as precoating chippings, being carried out in ordinary drum-mixers and that it may be heated either in its own drums or in secondhand empties and that the same grade may be used for both precoating and sealing. If, therefore, the provisional specification suggested above proves satisfactory it should be very adaptable to large scale work.

DISCUSSIONS ON PAPERS H—39, E—39 AND G—39.

Mr. A. Lakshminarayana Rao (Author of Paper H-39.) :—As we are hard pressed for time, I shall not take much time.

I wish to place a few points in introducing the paper, so that criticism may be passed taking those points into consideration. What I wish to achieve is an economic substitute for water-bound macadam. It has been found in practice by all of us that water-bound macadam is not able to withstand heavy mixed traffic of the iron tyred bullock cart and the fast rubber-tyred motor. It was my attempt to evolve a type of road as economic as possible to suit both these kinds of transport. I might straightaway state that cement concrete and other superior types are not ruled out by me: they are given up purely for want of finance. The district engineer who is in charge of a large milage of roads with a small amount to be spent on them, is like a man with a large number of children with a small salary. So the engineers who criticise my paper will kindly note that the whole attempt has been to evolve as economic a type as possible with the limited funds that are placed at the disposal of the district engineer.

One other remark I wish to make. Too much bitumen is considered by me bad for the roads, although it is good for the salesman. The advice that we frequently get from salesmen is "Use more bitumen"—that at least, is my experience. An attempt has been made to use as little bitumen as possible, and to try to make bitumen do the maximum amount of work with the minimum quantity that should be used. My attempt has been to make bitumen function as a binder and not as anything else.

With these remarks, I introduce the paper.

Mr. S. A. Amir (Author of Paper E-39) :—In introducing this paper hardly any explanatory remarks are necessary as no theories have been advanced nor something out of the ordinary has been suggested. The paper mainly gives detailed specification of our present day methods of surfacing work. There is however one point on which some explanation may be useful. This is about the method of attachment of a drag-broom to a power roller. When for the first time we used a drag-broom in 1938 with the assistance of Mr. Meares, it was attached to the roller by means of ropes and it was dragged by the roller in each trip either working forward or in reverse gear. At the end of each run, the drag-broom had to be detatched from one end of the roller and attached to the other to follow it again in the return trip. This not only wasted time but in every trip first the chips were being pressed down by the roller and then made to move by the dragbroom for being coated with binder and taking up position to give a level surface. It struck me that the reverse process *viz*: first moving the chips by dragbroom for coating and levelling up the surface and then pressing them down by the roller would be more logical and should give desired result quicker.

In subsequent work, I, therefore, arranged for the drag-broom being attached to the roller at the front by means of suitably designed angle iron linkage whereby it could both be dragged in the backward run of the roller and pushed forward in the forward run without having to be

detached and attached at the end of every run. Of course the drag-broom was so attached that it travelled squarely in the direction of the run of the roller and was free to move up and down always resting on the road This also solved the difficulty with which one is bound to be met in working the drag-broom attached by ropes on sections of road in curves. In actual practice, in the first forward run of the drag-broom in front of roller it is able to move and coat the chips better than what it would have been able to do if it had followed the roller after the chips had been pressed down. In the return trip, it does the same function as used to be done by each trip with the drag-broom attached by ropes behind the roller. In next forward trip before the moved chips are pressed by roller the drag-broom comes on them first and movement of chips, coating and levelling up is more efficiently done and then the roller follows and presses them down Again in the return trip the roller passes first on the chips for a second time and the stabilization of the chips which have taken up correct positions is more effectively done and there is less chance of their being unnecessarily disturbed again by the drag-broom In this way instead of every time one dragging following one rolling we have two rollings following two draggings and the number of trips and time required to achieve the result is greatly minimized. I would strongly recommend this method of attachment in use of the drag-broom to those who may be still using rope attachment and the advantage can be best realized after actual trial.

Mr. Fielder has very kindly given me an advance copy of his criticism and remarks about my paper. As his remarks regarding the concluding portion of my paper are not in the nature of criticism and do not clear the point I may be permitted to mention it at this stage so that he and others may have a chance of considering these and clearing the point at issue further.

I had the case in view in which the water-bound macadam is of the best type stone metal and properly consolidated which does not suffer from the traffic load and surface impact but the surface (painted) seal coat over it is not able to stand these. If a 2-inch premix carpet is laid over it with a ½-inch wearing course as suggested by him, this should also get worn quickly with the ½-inch chips at top getting crushed and being disintegrated, and renewal of this ½-inch wearing course should be necessary at about the same interval as if it was laid on the water-bound surface itself What advantage would the premix-work base-coat give in such a case?

Mr. Ian A. T. Shannon (Author of Paper G-39) :—I think that it is unnecessary for me to say much in presenting our paper. Our subject is familiar to most of you and we hope of interest to all of you It has been our aim not to write a theoretical treatise but to lay before you the conclusions which we have come to after fairly considerable experience of the use of Bitumen for Light Surfacings in this country. In some cases, our accumulated experience has led us to form conclusions which are somewhat contrary to those held in other countries, and perhaps in some parts of this country also. In these cases, particularly in the case of "two coats together" surface dressing, we have endeavoured to clarify the factors affecting the results obtained under Indian conditions, and it is for you to judge how far we have been successful.

On behalf of Mr. Vagh and myself, I present the paper for your criticism.

N. Durrani (Madras):—As the time is very limited I will state only a few points briefly, to be explained by Mr. A. Lakshminarayana Rao.

The first cost per mile of water-bound macadam is given as Rs. 2,400/- and the annual maintenance cost is written as Rs. 1,400/-. Details of this Rs. 1,400/- are not given.

The first cost of Bitumen-Bound Macadam is given as Rs. 5,600/- and its subsequent maintenance Rs. 1000/- as against Rs. 1,400/- of water-bound macadam. In working out the annual maintenance cost of Rs. 1000/- the depreciation on Rs. 5,600/- has not been taken into account as the original surface will require thorough re-doing after a certain time. In addition the depreciation on tools and plant also is not shown. I request the learned author to state how long the original surface costing Rs. 5,600/- can be made to serve usefully with an annual maintenance of Rs. 1000/- only and not more. Is it necessary to give precast cement concrete block curb or granite edging to the road? I think though it means a little money in the beginning, it is better to give fine finished edges as these are conducive to long life of the road and keep it fit.

I happened to serve in a district just for a while, where Mr. Lakshminarayana Rao's specification was in vogue. The riding surface is generally good and popular. As I was there only for a very short time, I could not gather full statistics and I request him to please clear my doubts.

Mr. M. L. S. Yusuf (Hyderabad-Deccan):—I must congratulate Mr. Lakshminarayana Rao, on his excellent paper. It is indeed, interesting to a road engineer, especially to one who is beset with meagre financial resources and yet desirous of constructing good roads for heavy traffic.

(*Please vide Page 3 h*).

The author quotes that the initial cost of "Bitumen-Bound Macadam" will be Rs 5600/- per mile, and the annual maintenance charges per mile are as under:—

1st year ..	.. Rs.	200	0	0
2nd year ..	.. Rs.	300	0	0
3rd year ..	.. Rs.	2500	0	0
Total for 3 years	.. Rs.	3000	0	0

Or Rs. 1000/- per mile per year.

The maintenance grant available is Rs 1400/- per mile per year The savings in maintenance bill come to Rs. 400/- per mile per year. At this rate it will take $5600 \div 400 = 14$ years to cover the initial cost (not taking interest into account).

On this point, I would like to mention that strictly speaking, maintenance amount of a road is meant to maintain the road, year by year, to its *original condition*. There are several items for the road engineer to attend to, besides the usual periodical reconstructions, by the neglect

of which heavy amounts are likely to be involved in due course To take advantage of special or emergent estimates for all such items is neither admissible nor advisable.

(*Please vide Page 4 h last two lines*).

The author quotes that he tried this specification in February 1937 in Krishna District and the road surface seems to have been standing well up-to-date, (*i.e.* two years have elapsed) From the figures shown it seems that the author is proposing to do surface dressing in the third year at the cost of Rs 2500/- (which is 46% on the original cost of constructing such surface). Results for the subsequent years are necessary to ascertain whether Rs. 1000 per mile per year would suffice to maintain such a surface. It is the cost for the third year which is high. Surface dressing is proposed by providing 3600 cubic feet of chippings (¼ inch to ½ inch)—thus a coat of uniform thickness of about ½ inch is expected over the whole road surface. In my opinion, such a surface will not withstand the strain of the intensity of traffic under discussion. Consequently, Rs. 1000/- per mile per year will not suffice and in my opinion, the aforesaid proposal is not an economical substitute.

I again wish to show my appreciation to Mr. Lakshminarayana Rao who seems to be striving to solve the problem of constructing a road to withstand modern traffic with meagre financial resources. We would be interested to know the further developments on his experimental surface treatment.

Mr. Ali Ahmed (Assam) :—I wish to say something about what we have done on lines similar to what has been proposed in Mr. Lakshminarayana Rao's paper and the results we have got We tried a similar method and I will give you the specifications. The water-bound macadam which has been re-shaped and is in fairly good condition is scrubbed of dust and dirt as required for surface painting work Ordinary road metal broken from hard rock or boulders to 1½-inch to 2-inch gauge, preferably washed clean with water, is spread over the road at the rate of 12 cubic feet per 100 square feet of road area. The metal is consolidated dry, with an 8 or 10-ton steam roller depending upon the hardness of the metal, until the stones are interlocked and do not move under passing traffic. Generally 15 trips of the roller (one up and one down) are sufficient for the purpose, but the road metal should not be crushed and the surface should remain open. Any stones which are soft and have been crushed should be removed and replaced by fresh metal. The dust formed on the surface should be removed by fanning with gunny bags. The edges of the metal carpet which will be about 1¼-inch thick after consolidation are to be lined with turf. No blindage is to be used during dry consolidation.

Colas is then sprayed over the carpet with a spray pump worked by a couple of men, at an average rate of 70 pounds per 100 square feet. It will penetrate into the interstices covering the stones almost on all sides. Even if it does not cover some parts of the stone metal which are wedged together hard, it does not affect the results.

As soon as the Colas emulsion breaks up (the dark brown colour changes to black within a few minutes of spraying), the road surface is covered with hard granulated chips (¼-inch to ¾-inch) or clean gravel of the same gauge at the rate of 2½ cubic feet per 100 square feet. This is

lightly rolled in the same manner as adopted for surface painting work. The road is now ready to be opened to traffic.

In fact, during the whole process, the road is never actually closed to traffic, except for the interval when Colas has been sprayed but not covered over with chips. In localities where rainfall is very heavy it is advisable to apply a seal coat with Colas or Mexphalte using 20 to 25 pounds per 100 square feet.

The cost of this type of consolidation of metal with Colas (excluding cost of stone metal used) is practically the same as for two coat Colas surfacing work for which 70 pounds of Colas per 100 square feet is required. The quantity of metal used in the work is the same as required for ordinary consolidation work.

A small experimental stretch was laid in mile 38 Gauhati-Shillong road in June 1934. A month after the completion of the work, it was found that the carpet had set hard and it was not easy to lever up a stone even with a screw driver. The surface of the road was not smooth like a painted road surface but was rather rough and open and non-skid, as no sealing coat was applied. No repairs whatsoever were found necessary until January 1937, when a sealing coat of Mexphalte at 35 pounds per 100 square feet was applied, because the surface looked rather open and rough although no pot-holes had formed. The surface is still in an excellent condition.

I think there is a future for this sort of consolidation with bitumen binder in those places where the traffic is moderate, *i.e.* where the traffic does not exceed 1,000 to 1,200 tons per day for a 12 feet road.

The same specifications tried in another place have also given very good results. So, I think where money is not plentiful, as Mr Lakshminarayana Rao said, this method can very well be adopted.

Mr. K. S. Ramamurti (Vizagapatam) :—I only wish to bring to your notice that I tried the method advocated in his paper by Mr. Lakshminarayana Rao in about 4 furlongs near Chilakalurpet in Guntur District, which is a big centre for bus traffic. Here the trunk road crosses a very important marketing road. The traffic was about 800 tons per day on a 12 feet metalled width and a berm of about 6 feet on either side. For nearly one year, till I was transferred from that district, I had occasion to observe that this bitumen-macadam was standing quite satisfactorily. No stone edging was done; berms were made up and surfaced with gravel. They have to be looked after carefully from time to time by the road gang.

It only remains for me to say that I confirm the data given in the paper on the basis of the above experience.

Mr. C. J. Fielder (Calcutta) :—I wish to comment particularly on Mr. Amir's paper. Those who are conversant with the roads of Chota Nagpur will, I think, agree that a very great improvement has been shown in the last few years, and we are indebted to Mr. Amir for having put down clearly the lines on which such improvement has been achieved. I have to comment on a few of the matters dealt with by the author in this paper.

1. He asks for advice on the subject of maintaining premix carpets and for justification of constructing such carpets.

A premix carpet is justified when the intensity of traffic load and impact is sufficient to cause appreciable local damage and disintegration to a water-bound macadam in a comparatively short space of time, even though the latter has been primed and sealed by bituminous treatment. This renders the maintenance cost unduly high on account of frequent re-sealing necessary as well as repairs to, and even periodical renewal of the water-bound macadam.

A point is reached, when it will prove more economical to provide the initial capital outlay for constructing a premix carpet which can be discounted over a period of years on the saving achieved due to the comparatively lower maintenance cost then involved.

A premix carpet must be designed to be capable of absorbing the traffic load and surface impact and afford complete protection to the water-bound macadam below from disintegrating influences. A 2-inch consolidated premix carpet, for example, should consist of a base coat with chip-topping 1½-inches in thickness, with a super-imposed wearing course of chippings (preferably premixed) ½-inch in thickness. All wear should be taken by the wearing course and renewal of this course is due when the larger metal of the base coat begins to be exposed. Renewal of the base coat of the carpet should not be necessary under normal conditions.

The author has not taken into account the protective effect afforded by a premix carpet to the water-bound macadam under heavy traffic loads.

One inch carpets are not so easy to justify as they are not appreciably thicker than two coats of painting, but they have better wearing qualities as the metal is more fully protected from disintegration when premixed.

One inch carpets should not be laid over a rough or very uneven base but they are proving very popular in some countries for re-sectioning and strengthening previously treated surfaces.

2. In specification VIII page 10 (e), the maximum temperatures of application for road tars are given. It is most important to remember that these are maxima and that, particularly for second and subsequent coats, the binder should be applied at the lowest possible temperature consistent with achieving the specified spread. The limiting factor is the actual temperature of the road surface, and it is often possible in this country to apply road tars at temperatures of 180 to 200 degrees Fahrenheit. By this means a longer life for the binder is achieved.

3. The quantities of chips specified in IX, page 11 (e), seem, rather on the high side for the quantities of binder given, *e.g.*, I do not think that 22 pounds of road tar in a re-seal would be capable of holding as much as 5 cubic feet of ¾-inch chips per 100 square feet and would suggest 4 cubic feet of ½-inch chips as more suitable. I am aware that the quantity of chips which can be absorbed by binders varies to some extent with the shape of the chip. But even so, Mr. Amir's figures are high.

He refers elsewhere to the use of sand with chippings in sealing treatment. Where the stone metal employed is of a friable nature and iron-tyred traffic results in attrition of the chippings, the inclusion of sand is sound practice. The sand by capillary action draws the binder over the upper surface of the chippings and brings about a cushioning effect which reduces the wear on the chippings. A similar effect has been achieved in Chota Nagpur by first laying a primer with sand into which the chippings of the second coat can bed themselves.

Brushing in 1½ to 2 cubic feet of medium good quality sand per 100 square feet of freshly painted surface can be strongly recommended under the circumstances referred to above.

4. Regarding treatment on curves and sharp gradients, I would suggest the introduction of painting with premix chips. Prime the surface with 20 to 25 pounds of Road Tar No. 1 (or 2) and spread 4 to 5 cubic feet chippings premixed with Road Tar No. 3 at 5 pounds per cubic foot.

This may be done as a first coat over water-bound macadam or as reinforcing treatment, adjusting the application of the primer or tack coat according to the nature of the surface under treatment.

On ghat sections, where curves are inclined to be sharp, this treatment has the following advantages: -

(i) Loose blindage is eliminated, thus giving much safer riding conditions on a non-skid surface.

(ii) Traffic can be allowed on the surface immediately on completion of the treatment.

(iii) Re-sectioning to the desired degree of super-elevation can be achieved with premixed chips in a single application.

5. The author finishes with a full specification for drag-brooming treatment, which he calls "Mix-in-Place Surfacing Work." This might lead to the impression that this specification has been fully approved and adopted, whereas I think I am right in saying that it has only been recently laid in a few experimental lengths and has to prove its durability. The relative costs of such treatment as compared with ordinary painting and 1-inch premix carpet would be of much interest.

It appears from this specification that, in all, about 36 pounds of binder and 7½ to 8 cubic feet of chippings are spread per 100 square feet and when it is considered that this includes the tack coat, the amount of binder seems on the low side.

Mr. Murrell reports the success in Australia of surface treatment by the drag-spreading or re-sheeting method using premixed chippings which might well give more favourable results than drag-brooming.

I should like to congratulate Messrs. Shannon and Vagh on their paper, but I do not propose to comment on it, except to say that the conclusions reached therein on the subject of surface treatment with bitumens do not apply in the case of Road Tar binders.

Mr. W. L. Murrell (Bihar) :—I have here four closely type written pages of remarks I had intended to make from this platform on the paper on "Light Bituminous Surfacings", a subject on which I have done a good deal of work personally, a lot of it along new lines. But our time is very limited, and I will not be able to do all that I had intended.

However, a copy of my intended remarks has been submitted to the Authors, and it is hoped that those unspoken remarks and the reply of the Authors will appear in print* in the Proceeding of this meeting.

There is one matter, however, on which I must say something now.

The Authors, when dealing with surface treatments, give details of the volume of stone chips required per hundred square feet for different surface treatments; but they do not mention the very important effect which the *shape* of the individual chips has on the volume of aggregate required per hundred square feet of spread binder.

I now propose to demonstrate to you what might be called "The New Zealand Hat-Trick."

In my *topi* here I have, not kangaroos nor kiwis, but some biscuits and two sheets of newspaper.

This piece of newspaper which I lay on the table represents the surface of the road which is about to be surface-treated with binder and stone chips.

This biscuit I now hold in my hand represents a single stone chip. It is flat, and has but little volume, considering its large basal area. It is, therefore, rather like the chips we get by crushing quartzite and similar stone in a granulating machine, especially if the grooves have been worn off the jaw faces.

The ink in the ink pot represents the supply of binder and, on the paper, I smear sufficient ink in an area about the size of the biscuit to represent the binder sticking the biscuit down to the paper. To heighten the illusion I place the biscuit on the inked area.

And I repeat this with a second biscuit and a second splodge of ink on the paper.

And again, and again, until there are six biscuits all sitting on six splodges of ink on the paper.

And now I produce from the hat six more biscuits, only these are all stuck together, all one on top of another.

This lump of biscuits represents a single good lumpy or cubical chip, such as is obtainable by hand breaking good tough stone like basalt, and even some of the quartzite family.

I take the second sheet of newspaper, also representing a road surface, and put a splodge of ink on it about the size of the base of our lumpy chip and, to heighten the illusion, I place the lumpy chip on this splodge.

Now, I hold the two sheets of newspaper, one in each hand, for you to see.

* These remarks of Mr. Murrell are reproduced on pages 27 (g) to 29 (g).

The one has six splodges of ink on it representing the amount of binder necessary to hold down a certain weight of chips.

The other has only one splodge of ink on it representing the amount of binder necessary to hold down the same weight and not much more than the same stack-volume of chips.

In other words, it takes six times the amount of binder to hold the flat chips as it does to hold the lumpy chips! (*sounds of amused approval from the audience.*)

Of course, the whole thing is exaggerated; but you can easily see that it is very easy to make a mistake of 50 per cent or even more in the quantity of chips required, if you do not consider the typical shape of the chips.

This is important because chips are very expensive, and one might easily find, when using flattish chips, that many are quickly scattered over the berms of the road by traffic, and so lost.

It should be remembered, of course, that the bulky chips give a much thicker wearing surface or carpet than the flakey chips, for the same quantity of binder used per hundred square feet.

The trick can, of course, be demonstrated to individuals by using anna pieces in lieu of biscuits.

To any who desire to go into this subject more fully, I would recommend a study of the subject "Average least dimension," discussed in File No. 8 "Road Aggregates" of "Collections in Australia 1939," obtainable from our Library, (catalogue No. I R C 66).

Before closing these remarks I would like to suggest an improvement in our Standard Specification of sizes for broken stone. at least so far as chips for surface treatment are concerned. The specification is given on page 177 of the Proceedings of the Second Meeting of our Congress.

It will be observed that the mesh specified is to be square mesh.

Now, would it not be better to substitute diamond-shaped mesh, to take at least part-account of this special effect of the thickness of the chip?

We have at our disposal for this purpose a whole series of British Standard sizes for expanded metal sheeting.

And this expanded metal would have a further great advantage.

We, who use the standard square mesh wire screens, know how the screens get messed up owing to the lateral displacement of the wires, which causes some of the holes to become much larger.

An expanded metal screen would not have this disadvantage and, moreover, it would be easier to fit into a wooden frame.

Such screens, of course, would be used at a fixed angle—say 30 degrees from the horizontal, and with the greater diagonals of the apertures in the horizontal plane.

The remarks which Mr. Murrell had intended to make (vide *his comments on page 25(g)*) *are reproduced below :—*

The paper "G—39" is excellent in many ways, and it is a pity that time allows one to refer almost solely to the points on which one cannot agree.

The initial admission that the Authors have no experience of binders, other than bitumen is sportsmanlike and handsome. Those who cannot obtain the other group of binders, the tar group, will know that the paper is of much more benefit to them than to those who can, and have to use tar as well as bitumen.

As regards priming coats, being one of the pioneers of this work in India, I am very glad to see that the utility of priming is at last beginning to be recognised here.

Some believers in priming consider that it has a cushioning effect between the individual chip and the piece of road metal below it, especially if the primer coat has been gritted. The chip thus cushioned is believed to have more chance of surviving a steel tyre

The saving in binder made by giving a priming coat first is much greater in practice than the Authors admit, *vide* Mr. Amir's paper page 11.

It would have been better if the authors had made a reference to tar also when stating that a good primer should be either a heavy asphaltic oil or a blend of soft bitumen with a heavy oil. They have seen Chota Nagpur where the use of tar as a primer is standard practice for hundreds of miles of road. They also know that in other countries like India, which have coal but no mineral oil deposits, tar or compounds of tar and bitumen are standard materials for priming.

As regards not blinding or not blotting the primer coat, the New Zealand practice quoted by the Authors agrees with the Australian practice. But here in India, it is difficult as yet to obtain a primer that will be absorbed by a water-bound macadam surface within 24 hours, as these overseas authorities insist that it should.

Finally as regards priming, the Authors' statement that it is safer not to open a primed surface to traffic which includes steel tyres, should be taken cautiously. Unless the primer has thoroughly soaked in, before the binder and chips are applied, it will certainly cut-back the binder and so cause bleeding In Chota Nagpur, where Road Tar No. 1 blended with sand is used for priming, it is customary to allow at least 2 months before applying the binder and chips.

When describing types of binders, the Authors appear to share the belief that 30—40 penetration bitumen is preferable to softer bitumen, as excess does not lead to so much bleeding. This view is entirely erroneous, but it was held also by certain more or less famous highway engineers in Australia before the Shell people there put them right. The very contrary is true.

As regards cut-back bitumens, these are excellent binders for light bituminous surfaces, especially for road mixes done by drag-brooming as described in a paper at our Calcutta meeting, and as introduced by Mr. C. D. N. Meares in Chota Nagpur and other places.

These cut-backs are also largely used in Road-Mix-Seal and Drag-spreading as done in Australia, *vide* Files 10 and 11 of "Collections in Australia 1939", to be seen in the Congress Library, (Catalogue numbers IRC 68, and IRC 69).

The chief reason why road oils or fluxed bitumen and cut-backs are more expensive than straight bitumen in India today is that we have to buy the former in expensive strong returnable drums, whereas the straight bitumen comes in very cheap non-returnable containers.

Though fluxing and cutting-back oils for making road oils and cut-backs from straight bitumen are more expensive than the straight bitumen itself, it does not require much of the former for the work of conversion. The process is simple enough *vide* file 7 of "Collections in Australia 1939", Catalogue No. IRC 65. I hazard the opinion that the bitumen interests in India ought to have put us wise as to this, years ago.

As regards blindage, trap is not really an igneous rock, but there are some points under this heading which I would like to criticise.

It would have been better if the Authors had stated exactly what they mean by $\frac{5}{8}$-inch to $\frac{3}{4}$-inch chippings. Did not all good Congressmen decide to stick to the Congress nomenclature, *vide* page 177 of Vol. II of our Proceedings?

The Authors have not referred to the effect of the typical *shape* of the chippings, as affecting the number of cubic feet to be spread over a given area of spread binder. It is well known that a given amount of binder will hold less chips if they are flat in character, as in the case of quartzite chips from a granulator, than it will if the chips are of lumpy or "cubic" shape. *Vide* File 8 of the "Collections in Australia" in the Congress library, Catalogue No. IRC 66, the Australians have adopted the New Zealand criterion called "average least dimension". This gives very closely the correct amount of chips to be spread, an important matter, as good chips are expensive everywhere.

Finally as regards blindage, I suggest that hardness, of itself, is not a good qualification for chips. Vein quartz is harder than most minerals, but it makes bad chips. Hardness must go with toughness, as in the finer quartzites.

As regards one-coat and multiple-coat surface dressing, I am disappointed that the Authors have not mentioned drag-brooming as an essential part of the process, especially with cut-back and emulsion binders. The drag-broom makes all the difference in the riding properties of the finished surface.

It may be of interest that I heard a new name for "surface dressing" in Queensland. It was called "flush sealing", implying that the surface was *sealed* by *flushing* it with binder.

I must confess I do not like that expression "Light Chipping Carpet". Why not call it what it is—a thin premix carpet? In the matter of spreading these premixed thin carpets, the Authors are most distinctly out-of-date. They do not mention the process of "drag-spreading", whether by the light or hand-drag for emulsion premixes, or by the mechanical drag for warm or hot premixes. *Vide* File 10 of "Collections in Australia" 1939, in the Congress library, Catalogue No. IRC 68., drag-spreading has completely superseded spreading by rakes or hand screeds.

Indeed, where the old surface is at all uneven, the method of drag-spreading these thin carpets is absolutely necessary, unless one does a mix-in-place. The Shell Company of Australia issue bulletins on this drag-spreader work—*vide* the File No. 10 referred to.

As regards "enlivening treatments", I confess that I am sceptical. What we saw in Calcutta was not a success. And can oxidised-bitumen be enlivened? Or could the average road engineer tell whether the hardening of the surface was due to a change in the binder itself or due to overloading of it with mineral matter? If the riding properties are good, why not strip off seal with chisel-ended hammers, and do a complete re-treatment in such cases.

The Authors' final suggestion for a "bitumen-chipped macadam" is interesting. I think this is the same as the Victorian "modified macadam", *vide* File 12 of "Collections in Australia 1939", in the Congress library, catalogue No. IRC 70., Modified macadam has been in use for several years and has already proved itself.

Before concluding, I would like to repeat that time does not permit expression of appreciation of the many individual good points in the paper. But one thing I must mention. It is the pretty device of the Authors to give us a good view of the forest before we come to examine the individual trees. They start with "A broad specification is.........." and then go on to deal with each aspect individually. Most helpful.

The Authors have trotted out their horses. There are one or two not upto weight, but the new-comers "Primer" and "Cut-back" are very welcome, even if only rating as foals. I suggest importing the Walers "Average Least Dimension", "Drag-spreader" and "Road-Mixer"—all certain winners, and very necessary if the Authors are to make the most of their chips.

Mr. N. Das Gupta (Calcutta) :—I would like to make it clear before I proceed with my comments on the very interesting paper presented by Messrs. Shannon and Vagh that my remarks have nothing to do with any business firm and that they represent my personal views only.

I may say that this paper is very valuable and of interest to all road Engineers, as it deals with the cheapest and most common form of road construction. I, therefore, propose to make a detailed comment on the various points raised by the authors for which I may require some time which, I hope, you will lend me in view of the importance of the paper.

My first objection is to the manner in which the question of primer has been dealt with. Instead of putting the claims for and against a primer, the authors, in my opinion, should have described the cases where priming coat is an advantage and perhaps absolutely necessary. The subject of priming seen from a different angle and in the light of its utility to Road Engineers would come in the following form:

1. What is a Primer, its composition, properties and behaviour on road?
2. When is this required?
3. Methods of its application for different cases.

As the authors have not discussed this important subject in a proper way, though it falls under the category of light surfacing, I feel that I should briefly discuss these before the Congress.

A primer may be road oil, cut-back asphalt or low viscosity Road Tar. As the main function of the primer is to penetrate into the road and to coat the blindage thoroughly upto a certain depth, usually ½ inch to 1 inch, this must necessarily contain some volatile oil plus bitumen But depending on the aggregate, blindage and traffic conditions, the viscosity of the primer and the percentage of bitumen in a primer will be different for different places and conditions.

For instance, in the case of stone-metal roads consolidated with sandy-clay blindage or for broken-brick roads, a more viscous primer containing as high as 70 per cent of bitumen may be used with advantage. The penetration will be very marked in view of the porous nature of the blindage in the first case and of the aggregate in the second case.

Again, for stone-metal roads with sticky-clay blindage or for close textured *kankar* or laterite roads, a thin primer must be used for efficient penetration.

As the consideration of Tar is out of the scope of the paper presented, I would only deal with cut-back asphalts and road oils for priming purposes. The authors have mentioned that "a good primer should be either a heavy asphaltic oil or a blend of soft bitumen with a heavy oil", without assigning any reasons for such a recommendation.

Before going into any detail, I would like to tell you the essential *differences between a road oil and cut-back asphalt.*

Road oil or residual oil is obtained from the stills during the fractional distillation of crude petroleum or crude oil, when the lighter factions such as Naptha, Petrol, Kerosene, lubricating oils, etc. have been removed. It is, therefore, a combination of asphalt and heavy oil which is non-volatile at ordinary temperature.

If this distillation is carried a step further, this heavy oil will be removed and the resulting product is asphalt which contains practically cent. per cent. bitumen. By combining this bitumen with different oils having different viscosity and volatility in different proportions, several grades of cut-back asphalts will be obtained. These products have been rationalised in the United States into the following products—Sc or slow-curing type, Mc or medium-curing type and Rc or rapid-curing type. Each type has been subdivided according to viscosities, such as Sc1, Sc2, Sc3, Mc1, Mc2, Rc1, Rc2, etc. For priming purposes, Mc1, is selected which is a medium-curing cut-back asphalt of low viscosity containing approximately 50 to 55 per cent. bitumen. Mr. W. H. Wood of Texas State Highway Department in his paper entitled "Selecting asphaltic products for various types of surface treatment" writes:

"In loose surface group it is essential that the surface be consolidated and hardened before the surfacing proper is placed. For this purpose an application of a medium-curing cut-back asphalt, usually Mc1 or Mc2 is used. Mc1 having low viscosity is admirably suited for this purpose in that it has the ability to penetrate a loose surface to a depth of one-half to one inch, being almost entirely absorbed by the surface but, due to differential absorption, to deposit its asphaltic

content principally in the upper part of penetrated depth, the volatiles being absorbed by the underlying fine material. Other types of asphaltic materials have been used for priming loose surfaces with varying successes particularly residual oils similar to Sc1 or Sc2. While such oils will penetrate some loose surfaces satisfactorily, there is little evidence of differential absorption and the result is that a somewhat soft or spongy layer of treated material will be formed, especially where sweepings are placed on the oiled surface to take up the excess oil. This spongy layer defeats the function of the primer which was to harden the surface as well as to bind it together. As will be shown later, this spongy layer may have an important influence on the tendency for some surface treatments to become slick due to blinding."

Also for closely bound surface like a stone-metal road with clay blindage, *kankar* or laterite roads, MC1 cut-back asphalt is recommended in view of its low viscocity. A cut-back with heavy oil, road oil or tar cannot penetrate into such surfaces.

I agree with the authors that a priming coat is not necessary for properly constructed water-bound macadam with good hard stone and suitable blindage, but this is absolutely necessary in the following cases :—

1. When road metal is either porous or of inferior quality such as soft sand-stone, limestone quartzite, *Kankar*, laterite or broken-brick. In all these cases, the road metal crushes considerably during consolidation and if attempt is made to clean the road thoroughly, the water-bound itself would work loose. A priming coat dispenses with too vigorous cleaning and presents a bituminized surface instead of a dusty road for receiving the second coat with hot bitumen.

2. When the blindage used in consolidation is sandy soil or silt for unavoidable reasons. The water-bound in such cases must be stabilized with a primer before a wearing coat can be placed over such surfaces.

3. In gravel roads where there is practically no mechanical interlock. These roads cannot also be cleaned properly without damaging the water-bound. The primer will increase the binding property of the blindage and make a stable road fit for subsequent treatment.

4. In extreme cold climates, such as hill stations. For roads in forest and marshy areas and during winter months, application of primer would greatly ease the method of surfacing and would result in a more uniform surface due to even application of binder. Attempts to paint such roads with straight bitumen would result in heavy application with subsequent bleeding and corrugations.

5. Where the wearing coat cannot be applied within the same financial year due to want of time or due to shortage of funds. It is always advisable to protect the water-bound by giving a priming coat with sand blindage in such cases. With fast motor traffic on all roads, it is no longer possible to maintain a water-bound for any length of time. A priming coat on the other hand can give dustless and waterproof surface capable of withstanding the sucking action of the motor traffic.

6. For low-cost roads, for which adequate funds are not available but which carry a large volume of motor traffic It would be cheaper to maintain such roads by giving liquid seals with a cut-back asphalt primer at intervals of 2 to 3 years, than by keeping them as water-bound

roads. These roads may be improved to a higher standard whenever desired, provided that such expense is justified and that funds are obtained for the purpose.

7. In places where skilled labour is not available, laying of hot bitumen over a coat of cold-laid primer is a fool-proof job and results in very strong and durable roads.

Coming to the question of application, we find that the authors have recommended application at 15 to 25 pounds per hundred square feet without blindage and have, therefore, totally ignored the question of the interval that should be given before the blinding material, usually sand, should be spread.

The authors have not shown any reason why a primer should not be blinded. I feel that this is practically impossible and also undesirable for the following reasons :—

1. Usually, the second coat is not applied immediately after the priming coat and that the speed with which a primer may be applied is far greater than the speed with which hot bitumen may be handled. It follows that about 10 to 15 days would elapse between the successive coats. It is not possible to keep the road closed to traffic for such a long time. Hence the necessity of blindage arises.

2. In case of narrow roads and specially hill roads, the roads cannot be closed during the night, the blindage must be applied to prevent the carrying away of bitumen by the wheels of passing vehicles.

3. It is intended that a primer should penetrate up to a desired depth, usually ¾ inch to 1 inch, and further penetration should cease after that. The sand blindage does this. While penetration is desirable, it is also necessary to see that the particles of the blindage penetrated should be effectively coated with bitumen to develop some strength. A very thin primer, say containing only 20 per cent bitumen would probably go down to a depth of 2 inches but this 2 inches of material will not develop the same strength as ¾ inch of material primed with a 60 per cent cut-back asphalt.

4. By exposing a primed surface for any length of time, it is allowed to catch road-side dust only which would eventually combine with the primer to form a thin brittle skin. The sand blindage spread after a specified interval would give a hard-non-abrasive mastic, which is far stronger than the dust mastic which is sure to form if the road is kept uncovered for any lenghth of time

It must, however, be understood that this blindage will be applied only when the penetration to the desired depth has taken place.

There comes the question of interval. For porous aggregate or blindage, it is an advantage to use a thicker primer, but the interval in such cases must be increased Usually an interval of 6 to 24 hours is recommended in such cases. For close-textured surfaces, a thin primer must be used and the usual interval in such cases is from 4 to 12 hours. With thin primer, such as MC1 on the first mentioned class of road, the interval should be 1 to 3 hours only.

As regards the rate of application, I consider the lower limit of 15 pounds as inadequate for covering 100 square feet of water-bound surface. The minimum rate is 22 pounds per 100 square feet for efficient application and the maximum is probably 30 pounds for rough or loose surface.

Mr. W. F. Fouslee Jr., of North Carolina State Highway Commission in his paper entitled "Asphalt Priming Materials—Character and use" writes :—

"It has been found necessary to use a prime application in the construction of low-cost pavements such as surface treatment and roadmix types. It is generally understood that a prime material should partially fill the voids and tend to solidify the base in question, help reduce capillarity and at the same time serve as an adhering coat for the next application to follow".

He also warns against the use of inadequate amount of primer, saying that :—

"When an inadequate amount of primer is used, it very often leads to failure and, therefore, maintenance becomes excessive. In most cases where an inadequate amount of primer is used the next application of bitumen will naturally act as an agent for the primer filling some of the remaining voids thereby reducing the quantity anticipated to hold the first application of stone, gravel, sand or blotter course."

From the above we see the importance of using adequate quantity of primer. Cutting down the quantity to a minimum would hinder the purpose for which a primer is used. As a rule, an application at 22 to 30 pounds per 100 square feet should be recommended, and the actual quantity for any particular work will, however, depend on the condition of the water-bound, nature of metal and blindage used, climatic conditions, and on the subsequent treatment to be given.

There are also a number of points where I differ from the authors, but the time at my disposal does not allow me to deal with those points. I would only discuss the question of blinding raised by the authors. They mention that smaller size chippings became "flooded" with bitumen after being spread over a fat spot. This is a simple phenomenon of hydrostatics and happens because the smaller chips get immersed in fluid asphalt and displace asphalt equal to their own volume which rises to the surface and floods the road. With larger chips no immersion takes place and, therefore, there is no flooding.

There is however, one danger in using larger chips. This will result in uneven and humpy road if not spread uniformly over the entire surface. I believe "sand" is the best cure for bleeding. The sand-asphalt mastic when formed, will provide a very hard non-abrasive skin which would also protect by cushioning the underlying base from the action of iron-tyred traffic.

There is one more point, I would like to mention. In classifying the light surface treatment, the authors have ignored the road-mix or mix-in-place construction altogether. The details of this process are fortunately contained in the interesting paper presented by Mr. S. A Amir at this session of the Congress.

Before concluding, I would like to point out that the definition of light surfacing by the authors given on page 2 (g) of their paper is rather vague and misleading. They mention, "....provide a wearing surface but will not be required to take up in themselves the traffic load and impact stresses which they transmit direct to the load-bearing road crust." I fail to understand how this is structurally possible. A layer which is transmitting a load must necessarily stand up to it and must take the load before transmitting it. In case of asphalt roads however, the ductility comes to the rescue and prevents tearing of the loaded carpet or sheet. When the load is passing through this sheet it must be strained. I think the definition given by Mr. W. H. Wood is more clear. This is as follows :—

"Such treatments are treatments of the surface only, provide a wearing surface and because of their very low beam strength and relative thinness cannot be considered as being capable of *distributing* (and not taking) the load but merely of transmitting it to the underlying base course."

Mr. R. A. Fitzherbert (Bombay) ;—The paper on "Light Bituminous Surfacings" is on a subject which is of the greatest importance to all Road Engineers in India, as it deals with some of the cheaper methods of road modernization. Some Local Governments show a great disinclination to increase road maintenance grants. It is, therefore, very important that we should arrive at the cheapest possible method of road maintenance.

The methods advocated in this paper are all comparatively cheap, but some of them would cost much less than Rs. 5 per 100 square feet or about Rs. 3200 per mile for a 12-foot width of road surface. As in this Presidency we can, as a rule, re-surface a water-bound Macadam surface 12 feet wide for about Rs. 1500 per mile, we need something cheaper than a surface treatment costing over twice this amount. In a few Provinces, the Public Works Department would appear to have been able to convince their Finance Department of the saving in road maintenance cost that road modernization can result in, but in most Provinces the Public Works Department is not so fortunate and is faced with inadequate maintenance grants for miles of water-bound macadam.

In this Presidency, we have some 7000 miles of road in the charge of the Public Works Department and the surface of all but a small percentage of these roads is water-bound macadam or *muram*. To maintain all these roads in good order, we require about Rs. 56 lakhs per annum, whereas we actually get only Rs. 30 lakhs. It is, therefore, evident that unless we can retard the rate of deterioration of our road surfaces, our roads are going to become even worse than before.

There are still many miles of water-bound macadam in India, the modernization of which must, of necessity, be deferred for years and most Provinces are faced with the same problem as we are in this Presidency. The question, therefore, arises as to what is the cheapest method of maintaining water-bound macadam under the existing traffic.

While the methods advocated in the Paper now under discussion have much to recommend them, I believe that a temporary solution of our problem may lie in the use of some kind of liquid asphalt or road oil which could be applied to the surface immediately after the blindage has been spread over a new water-bound surface.

What we require is a treatment costing as little as Rs. 1-8-0 to Rs. 3 per 100 square feet or about Rs 1500 per mile for a 12-foot width.

In this connection my attention was drawn to a method which has been adopted in Mile 34 of the Calcutta-Jessore Road and which we inspected last February at the time of the Fifth Annual Meeting of the Indian Roads Congress.

This method consists in treating the completed water-bound macadam surface with the Standard Vacuum Oil Company's liquid asphalt and then opening the road to traffic after 24 hours.

An alternative specification advocates a slightly different type of application, and the spreading of sand or road dust thereon. The cost is said to vary from Rs. 1-8-0 to Rs. 3 per 100 square feet.

By the adoption of this method, we should be able to stabilize the surface of our water-bound macadam, this being achieved by increasing the binding properties of the blindage, thereby increasing its resistance to traffic of all kinds.

If we can do this, we shall reduce road corrugation and also increase the strength of our water-bound macadam and thus its durability. My suggestion really amounts to accepting the author's proposal as regards 'Priming Coats' and stopping at that

This method is under trial by Executive Engineers in the Central Circle of this Province, but it is as yet too early to give you the results of the treatment.

I understand that *Terolas*, a product of the Burma Shell Company is suitable for stabilization of water-bound macadam at a very low cost and this preparation is also to be tried in the Central Circle.

Mr. O. C. Kutty-Krishnan (Madras).—The authors of the paper on 'Light Bituminous Surfacings' have suggested the possibility of carrying out light surfacing with bitumen as part and parcel of water-bound macadam consolidation May I place before the Congress a type of construction tried by me which has given very good results on sections of the Great Northern and Western Trunk Roads near Madras. Briefly, the specification is as follows.—

1. Scarify to a depth of 2 to 3 inches and remove all material over ¾-inch in size to the sides.

2. Spread all the remaining grit and dust and add further blinding material to give a 1½-inches thick layer of hoggin.

3. Replace the old metal plus sufficient new metal to give about 4 inches unconsolidated thickness.

4. Roll dry and wet while correcting for grade and camber until the hoggin just begins to flush upto the surface.

5. Apply 2 to 3 cubic feet sand per 100 square feet and continue wet *rolling until thoroughly consolidated.*

6. After an interval of 8 to 12 hours, brush off excess sand and apply a slow curing cut-back asphalt at 20 to 30 pounds per 100 square feet.

7. Allow it to penetrate for 2 to 4 hours, cover with sand just removed and open to traffic.

This type of surfacing will cost about Rs. 1200 per mile and it has completely eliminated corrugations. This procedure gives in effect a water-bound macadam but without its drawbacks. There is no loose blinding meterial in the interstices of the top layer of stones which are filled with a plastic compound of asphalt and sand. This sand-asphalt mastic remains malleable long enough to iron out and mould itself exactly to the interstices between the metal. The stone of the road continues to carry the actual traffic which. after all, is the ultimate condition in every form of road construction while the sand-asphalt mastic merely water-proofs and dust-proofs. At a later date, the mastic hardens sufficiently to carry a carpet which is bonded not only to the stone of the road but also to this mastic between the stones. At this stage it can either be simply re-treated with a cut-back asphalt and sand to replace wastage or settlement or carpetted with stone-chips and bitumen if traffic warrants it, to protect the stone of the road. For these re-treatments, the quantity of bitumen required is only half of that used for the original work.

Regarding the opinion expressed by the authors on the question of priming, I quite agree with them that priming is not necessary on an ideal water-bound macadam. But we seldom, if ever, work under ideal conditions and I think that, even under the most favourable conditions, a primer introduces a most desirable factor of safety.

Regarding the size of chippings, the authors say on page 7 (g) that they found "that the smaller chippings and the graded chippings became 'flooded' with the binder which did not happen in the case of larger chippings." In my opinion, this result is due to the fact that the bigger sized chips crush more readily under the roller and traffic than the graded or smaller sized chips, thus producing more material for the bitumen to absorb.

Mr. S. B. Joshi (Bombay) :—I referred the question of bituminous treatment of roads to a medical friend and he sends the following extract from page 55 of Illingworth's Text Book of Surgical Pathology: —

"*Shale Oil Cancer* :— This form of cancer has received especial study in recent years, particularly by Scott of Broxburn The tumour is almost limited to the West Lothian district of Scotland, where it affects those engaged in the refining of shale oil (paraffin). It is a carcinoma and occurs principally on those parts of the body exposed to prolonged contact with the oil; in half the cases it occurs on the scrotum, in 30% on the upper extremities and in the remainder mainly on the face. Usually the tumour appears in men who have served during ten to forty years in the refineries, and it is uncommon in those of shorter service. It often occurs many years after retirement from work.

Scott has shown that in most cases it occurs in men actually engaged in the refining process, and consequently in regular contact with hot oil. The cancer develops on a papular eruption or on a wart associated with a dermatosis such as frequently affects these workers. In other cases, however, the tumour arises in labourers who are little exposed to the oil and in them it is not preceded by an obvious dermatosis. Presumably in such cases there is an idiosyncrasy.

Mule Spinners' Cancer :—This is another form of paraffin carcinoma. It occurs in the "mule" spinners of Lancashire cotton mills, and does not appear to be known in cotton-spinning districts in other countries. The "mule" requires

constant lubrication, and much of the oil is sprayed off the machine, especially at about the hip level. The men are thinly clad, on account of the high temperature at which mule-spinning is carried on, and their clothes become saturated with oil. The cancer affects the scrotum, neck and arms. It usually occurs in spinners of twenty to forty years' service, and is often preceded by wart formation.

It is interesting to note that mule-spinners' cancer has shown a rapid increase of incidence in Lancashire during the past thirty years. This is believed to be related to the fact that the period 1850 to 1875 saw a gradual transition from the use of animal (non-carcinogenic) oils to mineral oils derived from shale or petroleum. Only after the latent period of forty to sixty years has the effect of this change become manifest—a disturbing observation when considered in regard to the possible effect, many decades hence, of the modern pervasion of other petrolates.",

Mr. G. B. Vaswani (Karachi) :—Mr. Lakshminarayana Rao has named his paper as "Economic Substitute for water-bound macadam," We, therefore expected that he would give us a specification which would be cheaper than water-bound macadam. But we find on going through his Specification that it is simply a process of semi-grouting without a seal coat.

On page 3 (h), foot Note (2) the author says, "There should be at least 6-inches of the metal crust on the road, of which 3 inches should be of hard metal," which means that the road should first be a water-bound macadam and then he suggests in his specifications that bituminous material should be spread over the surface at the rate of 48 pounds per 100 square feet and covered with ½-inch to ¾-inch granite chippings. I cannot understand where the economy comes in and what is the substitute for water-bound macadam.

If it is desired to get even better results and more economical road in the long run than this, I am of opinion that the surface should be given a thin seal coat after 6 months. By this method, the gravel spread in the first coat will be preserved before it is pulverized under traffic and thereby an additional layer of bituminous stuff about ½-inch to ¾ inch thick will be provided at a small cost, which will take the wear and tear of the traffic first, before the bottom layer is attcked. That would increase the life of the road and the subgrade would remain intact for years which would mean reduction in ultimate maintenance cost.

Mr. W. F. Walker (United Provinces) :—Mr. Amir advocates the painting of water-bound roads some years after they have been consolidated. This was done in 1928 on about 10 miles near Cawnpore. The roads had been consolidated 1 to 2 years previously and before they were painted with bitumen they had become somewhat uneven. They have become more uneven still as the years have passed. Repainting has kept the carpet in reasonable condition, but it has not removed the unevenness. In many cases it has been found necessary to reconstruct the miles because of this unevenness. I think it can be laid down as an axiom that a road which is rough and uneven when painted will always be rough and I think this of vital importance that surface painting should be carried out as soon as the newly consolidated road is dry if it is desired to obtain the best results. If the road surface is somewhat open, the paint will penetrate more easily and will produce what may be more like a semi-grout than a surface paint. This agrees with the conclusion no. 3 of Messrs. Shannon and Vagh's paper.

My own opinion is that bitumen of 80-100 penetration applied to a stone-metal surface immediately after consolidation at the rate of 50 to 60 pounds per hundred square feet will give the best results. Grit should be $\frac{3}{8}$-inch to $\frac{1}{2}$-inch in size and should be used at the rate of about 4 to 5 cubic feet per hundred square feet *i.e.*, as much grit should be used as the bitumen will hold. The average life of a painted road in the United Provinces is about 3 years under traffic upto 1000 tons on a 12 feet width. Many miles which have been painted to a similar specification, have lasted for 10 years without being repainted. This, I hasten to add, is in the hills under motor traffic with very little bullock cart traffic, but I think it will be agreed that these results are excellent. In order to correct any impression which may exist that we have spent all our money in cement concreté in the United Provinces, I may say that we have over 1000 miles of painted surface plus many grouted and some premixed miles. Out of these 1000 miles, probably two-thirds have been constructed without any priming coat, by what we call one coat painting. We have used almost every kind of material in the market.

The remaining one-third, say 300 miles, have been given a priming coat and then a wearing coat of paint. This we call two coat painting.

We have come to the conclusion that we have obtained better results with one coat work and propose to do more of this in the future.

In one mile near, Bareilly, I found that the bitumen had penetrated about $\frac{3}{4}$ inch and this particular mile lasted for 4 years before requiring a repaint. The traffic on this 12-foot width was about 2000 tons per 24 hours.

In another mile, near Etawah, sand was used instead of grit in surface painting with bitumen. After about 18 months the results are reasonably satisfactory. The surface is smoother and more slippery than it would have been if grit had been used and although the cost of the sand is only one quarter that of grit, yet I do not myself advocate the use of sand for surface painting.

Mr. Lakshminarayana Rao (Author of Paper H-39) ;—I will reply to the criticisms on the paper in the order in which they were made.

Mr. Durrani wanted details for Rs. 1,400, the annual maintenance cost of water-bound macadam. These are given below. The presumption is that the life of a re-coat is 2 years.

Therefore Cost per year is 2400/2	..	..	Rs. 1,200
Charges for blinding the mile 8 times with gravel	..	..	Rs. 128
Occasional patching	..	..	Rs. 72
	Total	..	Rs. 1,400

With reference to his remarks on the depreciation to be allowed on Rs. 5,600, I refer him to the last but one para on page 4 (h). As regards depreciation on tools and plant, what is needed in addition to the ordinary plant is a sprayer costing about Rs. 1,200, which generally lasts for 10 years; and the charges on this account will be trifling.

Mr. M. L. S. Yusuf remarked that the data given by me do not include maintenance of masonary works. In Madras Presidency, these

charges are not included in the estimates for 'Maintenance of roads'. If they are included elsewhere, corresponding addition is needed in the maintenance estimates.

Regarding results for subsequent years, I shall give figures in another paper on the subject next year. I may, however, state for his information that the surface is standing well up to date without any repairs worth mentioning. With regard to his fears that such a surface will not withstand the strain of the intensity of traffic under discussion and consequently the proposal is not an economical substitute, I can only request him to try the specification over a quarter of a mile and observe the results.

Mr. Ali Ahmed has given encouragement by stating that he has tried the specification in Assam but only with a different kind of bituminous material *viz*, Colas It matters little what kind of bitumen is used. Further this is not the place to go into the various types of bitumen With due respect to the manufacturers of bitumen, I must say that they are introducing the same material with different names given to them in different years, once calling it Spramex, another time "mexphalte" or "Colfix" etc., etc. This change in name is resorted to probably for facility of their reference and for attracting the attention of Engineers. 'Colas' is after all a bituminous emulsion.

Mr. Ramamurti also encouraged me by saying that he has been trying the specification for the last one year, and it has given him good results.

Mr. Murrell said that flakey material should not be used for surface dressing. He demonstrated with the aid of biscuits and a sheet of paper how the metal will give way, if it is flakey. We need not consider what is to be done if flakey material is used. The best way is not to use it at all.

Mr. Kutty-Krishnan wants to use a mixture of sand and bitumen for blinding, it means that chips will not go in between the interstices of stones and hence the surface will not be hard.

Mr. Vaswani wanted to know how it would cost less by adopting my specification. My reply is that it costs less in the long run. To his enquiry as to whether it is desirable to have a layer of chippings after six months, I have to state that my experience is that after six months the surface will be extremely fine and smooth and that it is not desirable to disturb it under any circumstances.

Mr. Joshi quoted from a letter written to him by a medical friend of his to prove that cancer was on the increase somewhere in Europe as a result of the use of Bitumen on roads We shall leave aside this doctor from Lancashire. The other day I met a doctor in Bombay. He was telling me that after the cement-concrete and bitumen-treated roads came into existence, the number of his patients suffering from pulmonary diseases had gone down! He also said that since many of the roads in Bombay had been treated with bitumen or concrete, the health of Bombay city had considerably improved. I was glad to learn that we Road Engineers had contributed towards the improvement of the health of the City.

Mr. S. A. Amir (Author of Paper E-39);—I must first of all thank Mr. Fielder for having given me in advance a copy of his comments on my

paper and particularly for the remarks on premix carpets but I must confess that it makes me no wiser. I wanted to know the utility of 1-inch to 2 inches premix carpet over a type of water-bound macadam which is well able to stand the cart traffic but which is to be surfaced to meet the requirements of fast moving (motor) traffic and the ordinary surfacing with ¾-inch to ½-inch chips on it is not able to stand the action of iron tyre of bullock carts. Mr. Fielder, on the other hand, started with the supposition that it is the water-bound base under the ordinary surfacing carpet which sustains local damages and disintegration to protect which the premix carpet is necessary. It was for this reason that I thought it necessary to mention it in introducing my paper but nothing further has been said either by Mr. Fielder or any other member to clear this point at issue.

I will now reply to the criticism made by Mr. Fielder

He has laid stress that the temperatures given by me in para VIII, page 10 (c), of my paper are not to be taken as the maximum permissible. I do not mean that the binder should invariably be heated to the temperature given. If a reference is made to the wordings used by me in specification VIII, page 10 (c), of my paper, it will be seen that I have stated thus:—

"When these attain a temparature of about 50 degrees below the maximum temperature laid down at which they are to be applied (230 degrees for road tar No. I, 220 degrees for Road Tar Nos II and III and 350 degrees for straight bitumens like Mexphalte 80-100, and Socony 105) regulation of fire will have to be carefully attended to so that at no time the maximum temperatures are exceeded".

I think, that is enough to preclude any possibility of these binders being over-heated. A direction, however, that for second coat work heating to a lower temperature at which binders can be spread properly under warm weather conditions will be advantageous, will improve the specifications.

Mr Fielder thinks that I have specified 5-cubic feet of ¾-inch chippings for re-seal work with Road Tar at 22 pounds per 100 square feet. This, however, is not so. On page 4 (c), under para 1 (a) it is clearly said that "¾-inch chips would suit original seal coat over roughish old water-bound macadam with Road Tars and for seal and re-seal work with straight bitumen" and again "½-inch chips—these would suit for re-seal work with Road Tars." It is thus clear that for re-seal work with Road Tar, only ½-inch chips are specified. As regards quantity of binder and chips for re-seal work with Road Tar, if reference is made to paras VIII and IX on pages 11 (c) and 12 (c), it will be seen that 22 pounds of Road Tar No. II is specified only for re-seal over sealed surface for which 4.5 cubic feet of ½-inch chips are to be used and not 5 cubic feet of ¾ inch chips which are for use with straight bitumens as it has already been definitely said that ¾ inch chips can only be used in re-seal work with straight bitumens.

In case of the "mix-in-place" surfacing work Mr. Fielder has remarked "this might lead to the impression that this specification has been fully approved and adopted, whereas I think I am right in saying that it has only been recently laid in a few experimental lengths and has yet to prove its durability."

I admit that I do not quite follow his remarks. After all what I have given in this paper is based on the present day methods of our works. The specifications of the same have been drawn up by me with a view to get them approved by proper authorities. Thus at present there is, strictly speaking, no sanctioned specification for any of the works detailed in my specifications and that for mix-in-place work is one of them which has been based on works carried out during 1938 and 1939 and which are promising to stand longer than ordinary surface dressing.

As regards comparative costs, I am sorry I have not the figures available here. If any one feels interested and writes to me I will supply the comparative costs of ordinary surface dressing and mix-in-place work. We have not done any premix work yet.

Again, regarding the quantity of binder mentioned in mix-in-place specification, Mr. Fielder remarks: "It appears from this specification that in all about 36 pounds of binder and 7½ to 8 cubic feet of chippings are spread per 100 square feet and when it is considererd that this includes the tack coat, the amount of binder seems on the low side."

Here again he seems to have overlooked one point and I would request for a reference to page 15 (e), sub-para (IX). In the 7½ to 8 cubic feet of chippings are included 1½ to 2 cubic feet of ¼-inch to ⅜-inch chippings spread dry on top of the chips mixed-in-place and spread, which on average are about 6 cubic feet per 100 square feet. 20 to 22 pounds of binder at the most should suffice to coat these 6 cubic feet of chips of ¾-inch gauge or even more and the rest 14 to 16 pounds gives a tack coat to the previously sealed surface. The quantities given are based on actual works done.

Mr. Walker has remarked that surfacing work should be done as soon after consolidation as possible. I have got no objection to this, rather it is certainly to be aimed at, in most cases. But in some cases where we cannot be very sure of the quality of consolidation work done or when there is some doubt about it, I think there is some advantage gained if the surfacing work is done even a year or two later if by that time the water-bound has stood well and is in sufficiently good condition. What happens in that case is that the water-bound macadam gets a chance of further consolidation and stabilization under traffic and one or two monsoons. Of course, if the water-bound macadam was not properly done, it will suffer in this period. This, however, I think is an advantage, because it will show us that the water-bound macadam is not of proper quality and any inherent defect in it shows itself before we surface it. This is better than the defect showing itself after the surfacing has been done on a doubtful quality of water-bound macadam and thereby the surface develops bad riding qualities. If any defect is noticed in one year, we may either postpone the surfacing till next consolidation or if it is not too bad, we may surface it by mix-in-place method and get better results.

Mr. Ian A. T. Shannon (Author of Paper G-39):—I have the somewhat unenviable task of keeping you a few minutes longer than you would like to sit. I will, however, be as brief as possible.

Mr. Murrell was the first to speak on our paper, and he brought up the question of the shape of chippings and the importance of that factor

in surface dressing. I agree with Mr. Murrell that the shape of the chippings has an effect on the quantity of bitumen required to hold a given quantity of them, and *vice versa*, but I think that under traffic conditions in this country we must go a little further than the theory of the " average least dimension. "

If Mr. Murrell will lend me his " topi " and other paraphernalia, I will try and explain what I mean *(takes " topi ", sheets of paper and biscuits from Mr. Murrell)*. Mr. Murrell has demonstrated to you how flat chippings represented by these biscuits *(holds up two individual biscuits)* require more bitumen represented by these blobs of ink *(holds up paper with blobs of ink on it)* than a cubical chipping *(holds up six biscuits stuck together and paper with one blob of ink on it)*. But what happens here in India where we have iron-tyred bullock carts is this *(crushes the six biscuits stuck together into fragments)—(sound of amused approval from the audience)*. Under iron-tyred traffic the chips get crushed and it is, I should say, the size of the crushed particles, with which we should be concerned rather than, or at any rate as well as, the initial size or shape of the chippings. There is considerable field for research on this question, particularly, in my opinion, into the relationship between the behaviour of the chippings under iron-tyred traffic and the quantity of bitumen required.

Mr. Murrell was good enough to give us an advance copy of his comments running into four typewritten pages which he has not had time to make, *in toto*, this morning. My colleague and myself have prepared an answer to them which we will submit in writing but meantime I would like to deal with two points he has brought up. The first of these is in regard to the use of a Drag-Broom. Mr. Murrell has taken us to task for our neglect of the Drag-Broom. Some six or seven years ago, I had a drag-broom constructed at Madras. At the same time, Mr. Vagh made one in Bombay. We tried them out on a few multiple-coat surface-dressing jobs and our separate experience has led us both to the conclusion that in regard to the even spreading of chippings they gave us very little advantage over ordinary coolie labour methods, certainly not enough to justify their use on small jobs in this country where labour is so cheap. If, however, large surface-dressing programmes are taken up, their use might be justified. The foregoing refers to their use for surface-dressing; for light carpets we consider that we have progressed considerably beyond Mr. Murrell's " Drag Broom Mix-in-Place " method and that the use of cheap home made hand-operated drum-mixers allows of far more accurate control and better finish than can be obtained by drag-brooming, and at the same time fits in better with cheap labour conditions.

Mr. Murrell has also brought up the question of " Drag-Spreaders". We have not recommended the use of these as we are very doubtful if they are suitable for general use in India. There is a point about their use which Mr. Murrell has not mentioned, and that is that they require the use of very fluid binders which are expensive. Two and a half years ago, I had the opportunity to study road surfacing methods in Malaya, where drag-spreaders and fluid binders were in use. At that time, I came to the conclusion that more viscous binders, which would not permit of the use of these spreaders would be at any rate more suitable for Indian labour and traffic conditions. This opinion has been strengthened now by advice from Malaya that over there, fluid cut-backs and drag-spreaders

have been largely abandoned and that many miles of light chippings carpets have been constructed recently by other and cheaper methods such as we have recommended for India. I do not want Mr. Murrell to think that we are unprogressive and consider everything that is used in other countries as being unsuitable for Indian conditions. Personally I should be very glad to help Mr. Murrell in any way I can to investigate the usefulness of the " drag-spreader " in Bihar.

My colleague and myself appreciate the trouble that Mr. Murrell has taken to read this paper and his constructive comments. There are many other interesting points which he has brought up which time does not permit me to deal with now but we will reply to them in writing.

Mr. Das Gupta also was kind enough to give us an advance copy of his very interesting criticism. Road-Mix and Mix-in-place forms of light construction have been dealt with in our reply to Mr. Murrell and leaving out the portion which does not seem directly to concern the subject matter of our paper, the rest of Mr. Gupta's comments may be classified under four heads :—

(1) He agrees with us that a priming coat is not necessary for properly constructed water-bound macadam.

(2) He suggests 22 to 30 pounds of Primer instead of 15 to 25 pounds.

(3) He considers that Primers should be blinded.

(4) He believes that sand is the best cure for bleeding.

I will say that we are grateful about (1) and do not feel at all strongly about (2). We entirely disagree with him on point (3), and are very doubtful regarding (4).

Mr. Gupta draws a distinction between 'taking up' a traffic load and 'distributing' it. Resilient super-imposed carpets are called upon to transmit part of the traffic load directly to the base; the remainder, as was pointed out by Mr. Fielder, they take up in themselves.

Light surfacings, which form the subject of our paper, to all intents and purposes transmit the whole traffic load directly to their base, and, therefore, it is not perhaps 'vague and misleading' to say that they do not 'take up' the traffic load themselves.

Mr. Kutty-Krishnan mentinned an interesting method of work of which I have no experience and, therefore, cannot comment upon.

Mr. Joshi mentioned the medical aspect of surfacing and has been answered by Mr. Lakshminarayana Rao. There is possibly one further point that might be mentioned, however. Tuberculosis is a great scourge in this country and there is no doubt that its spread is favoured by dust, which can be overcome by the light method of surfacing dealt with in our paper.

Mr. Fitzherbert drew a somewhat depressing picture of the high cost of even light forms of surface dressing as compared with water-bound macadam but Mr. Lakshminarayana Rao came to our rescue and pointed out that in some cases at least surfacing is a direct economy in itself apart from the obvious indirect benefits it provides. We do, however, see that we must do all we can to reduce the cost of light

surfacings, and that experiments should be carried out in this direction, and I think that I may speak for all manufacturers of good surfacing materials when I say that this is constantly our aim.

Mr. K. G. Mitchell (Government of India):—I promised to tell you something about the test track, and will now do so quite briefly. The test track has not so far come up to our expectations, for reasons I will explain. We had a certain amount of mechanical trouble with the plant. Nothing of the sort had previously been designed in India—and even probably elsewhere. The design was worked out especially to reproduce the action of slow moving wobbling bullock carts rather than that of fast moving motor transport for which test tracks have been designed elsewhere, and we have had a certain amount of mechanical difficulty, and breakages of certain parts. That, I think, has now been overcome. Secondly, we made a mistake regarding the severity of the test for surface treatment before it had been surfaced up by mixed traffic. We started with a load approximating to 1000 pounds per inch width of tyre and although there are heavier loads than this in many parts of India, it was too much without other and lighter traffic to surface the road and bed the chips in the binder. The soil of the sub-grade being poor, water-logging took place, and I understand that this is common in Bengal. So, we had a combination of—I won't say misfortunes—difficulties. When the mechanical difficulties had been overcome, the first set of tests had not proceeded far before the monsoon broke and it was strong in Calcutta, so that the combination of surface treatment not surfaced up by traffic, too heavy a wheel load, and heavy rain penetrating the seal destroyed the test lengths rather suddenly without giving us any very definite results. I believe, however, that profitting by our experience, we shall get valuable results in the future. It is seldom possible to get an experimental piece of apparatus absolutely right, from the outset.

I must now refer to the Papers just discussed which have been very interesting, and we are all, I am sure, very grateful to the authors for them. Four or five years ago we were talking almost in different languages about the same problems. I feel that in these discussions we have been talking in the same language and using standard terms and nomenclature. That is a very definite advance.

CORRESPONDENCE

Reply to Mr. Murrell's Comments* on Paper G-39 by Messrs. Shannon and Vagh, (Authors).

We appreciate the trouble that Mr. Murrell has taken to examine what we have written. We do feel, however, that he has, to a large extent, compared what we have written with what is being done in Australia. We could perhaps have tackled our subject from a similar angle and compared what is being done in India with current practice elsewhere but we decided to confine ourselves scrupulously to our experience in this country. This procedure may have narrowed our scope but it leaves us on a common ground for discussion.

In regard to the points raised by Mr. Murrell he had dealt in detail with priming coats and seems to agree in part with our

* These comments appear under discussion *vide* Pages 27 (g) to 29 (g).

conclusions although he would go further in support of them than we feel is justified in the light of present knowledge. To dissociate Tar and Bitumen in this particular problem, as we have to do, may make matters more complex but we feel that in supporting the gritting of priming coats, Mr. Murrell is really departing from priming coats and dealing with first coat surface dressings. Mr. Murrell remarks that it is difficult to obtain a primer in India that will be absorbed by water-bound macadam in 24 hours. There should be little difficulty in obtaining a primer that will do this and indeed such a material is at present being used on work at Dum Dum Aerodrome.

In regard to the grade of bitumen most suitable for surface dressing, we are afraid that our mention of 30/40 penetration bitumen must have been misleading; we had only intended to draw attention to the fact that some engineers do still use this grade in this country. In our opinion this is bad practice and we have clearly stated on page 14 (*g*) (C 3 a) that we consider that softer grades should be used.

In regard to cut-backs, we do not agree that their extra cost is in all cases chiefly on account of the extra cost of stronger drums. In the case of viscous cut-backs, there is no difference. In the case of semi-viscous cut-backs, the difference is perhaps largely on this account. In the case of fluid cut-backs such as cold application cut-backs, the difference is on account of both drums and, more particularly, the special solvents. In regard to the manufacture of cut-backs at site, we are definitely of the opinion that at the present stage of the development of these materials in India, the course is not advisable.

Mr. Murrell has inferred that there are no mineral oil deposits in India. This is quite incorrect, and mineral oil has been found in Assam and in the Punjab.

Mr. Murrell does not like our use of the term "Light chipping carpet" but would prefer the term "Thin premix carpet." In this connection we consider that the term "Premix" is generic covering mixes not only of stone but of stone and sand. We ,therefore, feel that the term "Light chipping carpet" is more accurate for the type of work described.

To turn to Mr. Murrell's remarks on chippings, he has caught us out badly over the $\frac{5}{8}$-inch to $\frac{3}{4}$-inch size. What we intended was $\frac{3}{4}$-inch Roads Congress standard. In regard to hardness, it is true that shape and toughness are of great importance and we only wish that we could arrive at some accurate method of linking the hardness, toughness and shape with the amount of binder required.

Several other points raised by Mr. Murrell, particularly the use of "Drag-Broom", "Drag-Spreaders" and the theory of "the average least dimension" of chippings have already been replied to at the conclusion of the debate at Bombay.

Mr. Murrell has been kind to our fillies but is anxious to see his Walers in front. We are all in favour of fresh entries but we hope that in time, suitable countrybreds will be found to fill a few places in the Good Road Stakes.

Comments on paper E—39 by Mr. S. Narayanaswami Iyer, (Vellore).

It would be useful if the author could kindly furnish details as to the quality and thickness of metalling which was originally consolidated

and taken up for surface treatment, and referred to by him on page 2 (e). I would also request the author to give us an idea of the life of the water-bound macadam surface so as to enable us to judge the comparative merits of the two surfaces.

It is said that the metalled surface consolidated so far back as 1929, was found quite good to receive surface treatment in May 1938. This indicates that the surface had withstood the wear and tear of traffic for a period of 9 years without deterioration. If that were so, its life might probably be extended by another 3 years more, without the surface dressing and the consequent additional cost. Unless we are in possession of figures, as to the comparative costs, we will not be in a position to decide, which would be more economical, whether remetalling at the end of 12 years or surface dressing of the old surface.

Reply to the above comments by Mr. Amir (Author).

Regarding Mr. S. Narayanaswami Iyer's remarks, I have to reply that no records are available to show the thickness of metalling done on a certain section of Grand Trunk Road (216th. mile) in the year 1929. Usually for reconsolidation, 3 inches thickness of new metal is added and the same may be presumed to have been done in this case. The metal is white quartzite which we call "Bone" metal. Every one in charge of metalled roads must have experienced that for some reason or other a particular length of water-bound macadam stands much longer than the average life. The same was the case on this section and there are still some quarters on Grand Trunk Road which have not been reconsolidated since 1929 or 1930, but these are only exceptional cases. I think in old days when consolidation was done with heavy hand or bullock-drawn road rollers and there was not much of motor traffic, the consolidation work had chance of further stabilization under slow traffic in subsequent rainy seasons and some of them gave exceptionally long life. But on an average, under present conditions, a water-bound surface under heavy fast moving lorries and cars requires reconsolidation in 2-3 years time. Therefore there is no getting away from surface treatments of roads carrying fast moving motor traffic. The 1929 consolidated length was sound as a foundation but was roughish and its riding quality had suffered and could not be left as it was. Therefore, instead of reconsolidating it and then surfacing by ordinary methods, it was surfaced with mix-in-place method and thereby a saving in cost was made. Cost of reconsolidation and surfacing works out to about Rs. 2/- more than cost of surfacing by mix-in-place method with Road tar and Socofix without reconsolidation. The work done is standing well and promises to give more life than ordinary surfacing (painting) work. It is hoped this clears the points raised by Mr. Iyer.

Comments on Paper G—39 by Mr. S. A. Amir.

On page 3 (g), para 3, the authors say that 15 to 25 pounds of primer per 100 square feet should be probably sufficient. I don't know if it may be possible to cover the whole area with any bitumen primer but in case of Road Tar No. I, even with 30 pounds per 100 square feet, it is not possible to cover fully even the best water-bound macadam. The binder mostly remains sticking on the top of metal pieces and

cannot be made to flow in the interstices and it is the mastic which forms with sand blinding which is forced into the interstices under traffic and seals these up.

On page 4 (*g*), para (4), blindage of primer coat is depreciated. Condition to do without blinding *viz*: the primed length of road not being required to be opened to traffic before applying the final seal cannot be satisfied in actual practice.

Provisional specification for what the authors call "Bitumen-chipped macadam" is interesting and worth trying. Instead of laying the new metal directly on the brushed old water-bound macadam surface, it may be better to lightly pick up the latter so as to remove the top layer of metal and then brush the surface clean and lay the new metal by hand-packing to template. The advantage anticipated is obvious. The new metal will have better hold on the picked surface and hand-packing to template will also be easier and in rolling the surface should level up better.

Reply to the above comments by Messrs. Shannon and Vagh (Authors).

In their reply to Mr. Murrell's comments the authors have said that "priming" seems to have been confused with "first coat work". This statement is borne out by Mr. Amir's remarks His reference to a minimum of 30 pounds of binder per 100 square feet and to the mastic of sand blindage being forced into the interstices of the stone clearly show that he is referring to first coat work.

The authors' remarks relate to pure "primers" and not to "binders" with a priming action. The former are intended to be completely absorbed or as nearly complely absorbed as possible, by the road without leaving any free binder on the surface. The latter are intended to leave as much free binder as possible on the surface, with some absorption. Therefore, the two are not the same.

If this primary difference is borne in mind, it would become at once clear that where there is no free binder on the surface there is no need for any blindage. As regards the rate of application this depends on the viscosity of the primer and the texture of the surface and for a pure primer a quantity of 15 to 25 pounds has actually been found to be sufficient for the purpose.

As regards the condition about the road not being required to be opened to traffic it may be mentioned that fluid primers are absorbed rapidly and it has been possible to apply the Primer on one day and follow it up the next with seal. In fact by entrusting the priming work to the cleaning gang, it is possible to carry out a normal surface dressing work without any loss of time.

In regard to our suggested "Bitumen-chipped macadam" Mr. Amir's suggestion lightly to pick the existing surface before laying the metal course of Bitumen-chipped macadam has already been tried and found to have two drawbacks, (1) it is difficult to have uniform picking all over the surface. The result, therefore, is that where the picking is overdone the "hoggin" works up through the metal leaving insufficient space for the proper embedding of the chips so that the "anchoring" of the chips is not uniform, (2) it is necessary to water the picked-up surface so that the

metal may be embedded in it. This makes it necessary to expose the metal for drying for a day or so during which time it gets dusty. It has been found difficult to remove this dust, since the metal being only lightly consolidated cannot stand brushing. Where these objections are not considered serious, however, picking may be carried out.

Comments on Papers H and G—39 by Mr. Jagmohandas T. Mehta.

The cheap substitute suggested by Mr. Lakshminarayana Rao requires 48 pounds of bitumen per 100 square feet. The method is merely partial grouting with some saving in the amount of bitumen used. It entails use of water for consolidation and it is doubtful whether after 48 hours the body of the road would have dried. The Bitumen-chipped macadam method, suggested by Messrs. Shannon and Vagh requires about the same quantity *i.e.* 50 pounds of bitumen per 100 square feet, and it will give practically a carpet 3 inches thick in which the interstices are filled up with bitumen-coated chippings. This certainly is a better and more scientific method. I think it is better than even laying a 1-inch thick carpet superimposed on the subgrade. Such a carpet would be very difficult to bond to the subgrade. The cost of "bitumen-chipped macadam" will not exceed that of 1-inch carpet. The only thing I would like to suggest is that the size of the chippings should preferably be $\frac{1}{8}$-inch to $\frac{3}{8}$-inch so that these might readily wedge themselves in the smaller voids.

Reply to the above comments by Messrs. Shannon and Vagh (Authors).

Mr. Jagmohandas T. Mehta has clearly brought out the features of our suggested "Bitumen-Chipped Macadam" specification which we consider, make it a method of construction with definite possibilities. In regard to the size of chippings this will have to be related to the size of the metal used for the body of the carpet. In our provisional specification, we have provided for $1\frac{1}{2}$-inch to 1-inch metal and in the light of further experience since our Paper was written, we are inclined to agree that with this size metal, $\frac{1}{4}$-inch chippings may be better, although possibly still better results could be obtained by retaining the $\frac{1}{2}$-inch to $\frac{1}{4}$-inch chippings and increasing the size of the metal to $2\frac{1}{2}$-inches to 2 inches.

In conclusion we would emphasise that the specification is purely provisional and that considerable further work will have to be done with this method before a final specification can be recommended.

Comments on Paper H—39 by Mr. S. A. Amir.

Experimental work with very nearly the same method as d in this paper has been tried in the Hazaribagh Division. The idea it was not so much economy as combining consolidation and for simplifying the procedure commonly followed by us by reduc number of operations and also for preventing the chippings in the from being crushed and destroyed under cart wheels as a r their taking positions within the interstices of the top layer of al The work was done under the following instructions:—

"(1) Picking up may be done and picked metal may be screened to give firsts, seconds, thirds and fourths as usual.

(2) Over the cleaned subgrade the fourths should be spread evenly and over it first the old metal and then new metal should be carefully hand-packed to template.

(3) Reconsolidation should go on as is usually done except the final operation of putting in fourths and polishing. It is expected that the fourths laid below will work up sufficiently and that after rolling well with thirds the interstices will still be sufficiently open to admit binder and chips. Water to be used sparingly.

(4) The traffic is to be kept off the road for 3 days and after this, sealing is to be done. 55 pounds of Road Tar No. 2 should be laid and it should be covered up with $\frac{1}{2}$-inch chippings 3 to 4 5 cubic feet per 100 square feet and rolled in and traffic kept off for a day more.

(5) Spread sand at the rate of $1\frac{1}{2}$ to 2 cubic feet per 100 square feet and work it in with broom and open road to traffic."

2. The work is a year old now and is standing well. I got the top piece of metal taken out at some places to know the extent of penetration. It was found that it was not uniform. At some places the Road Tar had reached the bottom of the top piece of metal but not all round it and at others it remained confined to about $\frac{1}{4}$-inch or so from the top. This is bound to happen unless the interstices between metal are all fully filled in by the usual last polishing operation of consolidation and then taking these out up to $\frac{1}{2}$-inch to $\frac{3}{4}$-inch by wire brushing before laying the binder. With application of 55 pounds or so of the binder one can not expect to cover the top layer of metal fully.

3. One point further requires consideration. What is to be done when the metal at the top, not covered by chips, starts wearing. The author of the paper suggests maintenance by patching for 2 years and, in third year, resurfacing with $\frac{1}{2}$-inch to $\frac{1}{4}$-inch chip blinding. If nothing better is possible, subsequent maintenance and its cost will be just the same as in the ordinary light surfacing works over ordinary water-bound macadam, as the chips on the surface will get crushed under cart traffic as usual. It has been suggested to me to confine subsequent resurfacing to a light application of bitumen blinded with sand only at intervals of about 2 years or so whereby the metal will be saved from wear at smaller cost and the re-seal itself will not cut under cart wheel. This has to be tried to know its worth. However, the simplicity of operation and some saving in cost of the initial operation will still be in favour of this method.

Reply to the above Comments by Mr. A. Lakshminarayana Rao (Author).

Mr. Amir referred to an experiment carried out on similar lines in the Hazaribagh Division, and said that picking up might be done and that picked metal might be screened to give firsts, seconds, thirds and fourths etc. There are no details about what these firsts, seconds and thirds etc. mean and I am, therefore, unable to answer his criticisms.

In another place he had stated "one point further requires consider-ation. What is to be done when the metal at top, not covered by chips, starts wearing,"

Well, I hasten to say that that is the ideal condition required for the road. If stones appear on the top and are wearing out, I consider that to be the ideal type of road. If the tops of stones are perfectly horizontal and the stones are evenly spread, we will find that even after 3-4 years they will not have worn out to any significant extent.

It has been suggested that subsequent treatment may be a light application of bitumen blinded with sand only. That has been tried by me and it was found that it only consumes money but does not give satisfactory results.

APPENDIX I

REPORT

OF THE

TECHNICAL SUB-COMMITTEE

TO THE

Council of the Indian Roads Congress

FOR THE YEAR 1939.

(Considered by the Council vide resolution No. 3 of its proceedings dated 8th December, 1939 and accepted with remarks reproduced at Annex D, page 23).

The Sub-Committee regret that for various reasons they have been able to meet once only since the Congress Session in Calcutta. The Committee should endeavour to meet at least twice during the next twelve months.

The Committee met on the 6th December 1939 and the minutes of that meeting are as follows :—

Minutes of the Meeting of the Technical Sub-Committee held at Electric House, Bombay on December 6, 1939 at 3-30 p.m.

The following were present :—

Mr. K. G. Mitchell C.I.E., (*President*).
Mr. J. A. Stein.
Mr. W. L. Murrell.
Mr. R. A. Fitzherbert.
Mr. Syed Arifuddin.
Mr. Ian A. T. Shannon.
Rai Bahadur S. N. Bhaduri.
Mr. Jagdish Prasad (*Secretary*).

Mr. C. J. Fielder was co-opted in connexion with the discussions on the use of "primers" on water-bound macadam.

Item No. 1 (See Annex A, page 18).—*Mr. Murrell's proposal for standard specification for hot and cold bituminous (including tar) primers.*

It was agreed that while Tar No. 1 (applied hot), is a satisfactory primer for water-bound macadam, new or in fair order, a surface primed with it could not be surface-treated for 2 or 3 months and had to be blinded with sand, while for dirty or broken down macadam and inferior

surfaces a cold primer is believed to give greater penetration. It was thought, therefore, that for dusty roads and for normal work on District Board roads a cold primer might be preferable, and that it would in all cases have the advantage of allowing the application of the main paint coat within a few hours. It was arranged that Messrs. Shannon and Fielder would supply cold and semi-hot bitumen and tar primers respectively, the trial of which Mr. Murrell would arrange in Chota Nagpur, the special primers to be supplied at normal rates. Mr. Murrell will provide liaison between the Technical Sub-Committee and the work in the field.

Item No. 2 (See Annex B, page 22)—*Grades and Curves.*

The Committee considered Mr. Chance's suggestion that gradient along curves, as previously recommended by the Committee, should vary according to the radii and recommend that, since the original specification related to hill roads in difficult country, the addition proposed by Mr. Chance was not necessary. The Committee, however, recommend that the original specification be amended to read as follows :—

"The gradient at curves should not exceed 1 in 30 and should be as flat as possible for 100 feet above hair-pin bends, even if it is necessary to increase the gradient for a short distance beyond this length of 100 feet."

Item No. 3 (See Annex C, page 22).—*Publication of particulars of bridges.*

The Committee considered the question of publication of the collected particulars of road bridges in book form and decided that the particulars collected in respect of about 100 bridges together with small scale skeleton drawings of cross-section and part longitudinal section, be published, provided that the cost of 750 copies does not exceed Rs. 1,000/-.

ANNEX A.

At its meeting held on the 25th May 1937, the Technical Sub-Committee expressed the opinion that "the use of a primer with sand as first step in surface treatment followed by a second coat of stone chips bound with some bituminous material would probably give excellent results" and decided to test it on the test track.

It has been proposed (by Mr. Murrell) that a suitable specification for a cold primer to be used on water-bound macadam before surface painting should be evolved. For this purpose, suggestions from members of the Sub-Committee, particularly those connected with the manufacture of tar and bitumen, might be discussed at the meeting. (It is hoped that suggestions will be forthcoming).

In this connection extracts from "Highway Design and Construction" by Bruce and "Book of Instructions" of the Country Roads Board, Victoria, are enclosed for perusal.

EXTRACT FROM " HIGHWAY DESIGN AND CONSTRUCTION "

By Arthur G. Bruce.

PRIMING MATERIAL:— The introduction of the priming application is the most important development in surface treatments in recent years. Before this step was introduced, the bituminous meterial and its cover was like a carpet laid over the road surface. It very often buckled under truck traffic, broke away from the base, and came off in large slabs. The purpose of the priming application on a bonded surface is the same as that of using linseed oil with a little paint on a wall or woodwork; it seals the pores, waterproofs the surface, removes the film of dust on the surface to be treated, and insures a good bond between the bituminous carpet and the road surface.

The priming material must have a low initial viscosity in order that it may be thoroughly absorbed by the surface being treated; in other words, the primer must be very thin when applied so that it will penetrate quickly and readily into the original surface. However, after the absorption has taken place, the primer should gradually harden and develop cementing qualities For treatments with asphaltic material, one of the best types of primer is the cut-back asphalt specified in Table 15. It is a combination of a paving asphalt and a distillate that carries the asphalt cement into the upper portion of the original surface and then separates from the asphalt by being absorbed into the aggregate below rather than by evaporating and passing off into the air. Where a tar treatment is to be provided, a tar of low viscosity is used for the priming application. A topical specification for such material is shown in Table 21.

TABLE 15.

CUT-BACK ASPHALT FOR SILTY SUBGRADE.

Viscosity, Furol, at 77° F.	40 to 150
Distillation, per cent by volume:	
Total distillate to 473° F., not more than ..	10
Total distillate to 600° F., not less than ..	25
Total distillate to 680° F., not more than ..	30
Tests on residue from distillation at 680° F.:	
Penetration at 77° F., under 100 grms. for 5 seconds	70 to 300
Ductility at 77° F., not less than	60
Per cent soluble in carbon disulphide, not less than..	99.5

TABLE 21.

SPECIFICATIONS FOR A PRIMING TAR

Specific gravity, at 77° F. (25° C)	1.10 to 1.18
Water content, per cent, not more than	2
Free carbon, per cent	2 to 10
Specific viscosity, Engler, 50 c. c. at 104° F. (40° C). ..	8 to 13
Total distillate, per cent, by weight:	
To 338° F. (170° C).	5
To 572° F. (300° C).	40
Softening point of residue, cube-in-water method, not more than	149°F.

PRIMING MATERIAL :— The material for the priming application is spread over the road by means of an approved pressure distributor, (one type of which is illustrated in the book). All machines are alike in having the bituminous material discharge through horizontal pipe fitted with nozzles, but the various types differ in the way the pressure is developed. Both asphaltic and tar primers are usually applied cold in normal summer weather; but, in cold weather, the primer should be heated to a temperature of 125° to 140° F. and it may even be warmed slightly at summer temperatures, in order to obtain greater penetration. For a bonded surface, the amount of Primer should be about 0 25 to 0.35 gallon per square yard, the exact quantity depending on the character of the surface to be treated. As a general rule, no cover coat is applied over the priming material, because the oil should be entirely absorbed by the old surface. However, in some cases, it may be desirable to apply a light covering of material that was previously swept from the surface. If a cover is used, the surface should be dragged with a broom drag, (such as that shown in the book), immediately after the cover has been put on

When a bonded surface is being treated, traffic should preferably be kept off the primed surface for a period of 24 to 48 hours If the road cannot be closed to traffic, half of the road is usually primed at a time while the traffic is carried on the other half; but the primed surface of the half first treated should not be exposed to traffic any longer than is necessary for the complete absorption of the primer on the other half, which absorption usually requires from 2 to 4 hours. The body coat should be applied as soon as the primer has been completely absorbed.

EXTRACTS FROM THE "BOOK OF INSTRUCTIONS" OF THE COUNTRY ROADS BOARD, VICTORIA.

Division 2.—Section 2. Primers.

1 *Nature and Purpose.*

A primer is a slow hardening material of low viscosity and low surface tension. It is applied to a pavement before the binder. Its properties enable it to penetrate the surface and coat the fine particles and dust with bituminous or tarry material.

In the case of surfacing materials which contain no large particles, the primer will stabilize the top layer and so provide a layer intimately bound to the pavement and to the seal coat which is later applied, which is of sufficient strength to prevent displacement of the seal coat under traffic.

If the surfacing material contains large particles, the primer enables the binder which is subsequently applied to come in intimate contact with them so that the seal coat is firmly attached to the pavement.

Conditions intermediate between these two will, of course, occur

Where the surface of the pavement presents a large area of stony material without any covering of fine particles, the binder is able to come in intimate contact with the surface of these stones which are firmly embedded in the pavement A primer can, therefore, be omitted under these circumstances. Where this possibility exists, the advice of the Board's District Engineer shall be obtained.

Where the pavement material is deficient in elutriable material passing 200 mesh sieve the surface should be stabilized by the use of a heavy primer. The grade of heavy primer is dependent on the nature of the surface of the pavement and in all such cases the Board's District Engineer should be consulted

Light Primer.

The light primer which will normally be supplied is a partially dehydrated side tar complying with the following requirements:—

(a) Water content not more than 5 per cent by volume.

(b) Total bitumen soluble in CS_2 not less than 83 per cent. by weight.

(c) Viscosity at 122 degrees F. in c g. s units shall be not less than 0 22, nor more than 0.55 poise.

For purposes of requisition, this primer shall be called "Cold Tar."

Normal rate of application 0.2 gallon per square yard.

Medium Primer.

If, with a well consolidated dense pavement on a sound base being maintained pending the application of a double coat first seal, it is desired to retain the existing surface and delay the application of the seal for a period of upto four months, a medium primer having a viscosity of from 1 to 2 poises at 120 ° F. covered with No. 4 aggregate can be used.

Primer.

80/100 penetration bitumen 100 parts by volume. Dehydrated tar 600 parts by volume. Temperature of mixture at the time of its application 170-180 degrees F. Rate of application of the mixture 0.25 gallon per square yard.

Aggregate.

Aggregate No 4. Rate of application 1 cubic yard to 100 square yards

Heavy Primer.

On pavements in which there is a shortage of elutriable materials which produced a weak surface of open texture as is the case when poor buckshot, scrub, or sandy gravels are used, a heavy primer, that is one having a viscosity of from 5 to 15 poises at 122 degrees F. should be used to stabilize the surface.

Either of the following slow curing road oils can be used at the rate of 0.2 or 0.25 gallon per square yard, depending on the texture of the surface to be treated.

(*a*)	80/100 penetration bitumen	..	100 parts.
	Asphaltic oil	..	100 parts.
	or		
(*b*)	80/100 penetration bitumen	..	100 parts.
	Dehydrated tar	..	150 parts.

2. *Rate of Application.*

The rate of application should be such that, provided the air temperature during the day exceeds 60 degrees F., the primer will be absorbed by the surface within 24 hours. Should it be found during the work that a longer time is taken, the rate of application should be reduced down to 0.15 gallon per square yard. Normally, the rate of application may be taken as 0.20 gallon per square yard.

A heavier application than 0.20 gallon per square yard will, in the case of pavements composed of fine material, tend to soften the top layer, while in the case of material containing large particles it is unnecessary. If, owing to lack of fine materials, it appears that the heavier application is essential, a heavier primer is indicated instead.

ANNEX B

The first recommendation of the Technical Sub-Committee was that "the gradient at curves should not exceed 1 in 30 and should be flat at hair-pin bends". Later, in view of the criticism offered by Mr. Murrell, the Technical Sub-Committee, at their VIII Meeting held at Simla on the 29th August 1938, recommended that "the Gradient along a curve and for a distance of not less than 100 feet on the up-grade side should be as flat as possible and in no case to exceed 1 in 50 even if it is necessary to increase the gradient for a short distance beyond this length of 100 feet". This revised recommendation of the Technical Sub-Committee was accepted by the Indian Roads Congress.

Mr. P. V. Chance, I.S.E., Chief Engineer, Central Provinces and Berar, has now suggested that the gradient along curves might vary depending upon their radii. He thinks the following limits to be satisfactory for the curves mentioned against each.

1 in 50	..	For curves of 200 feet radius and less.
1 in 40	.	For curves of radius greater than 200 feet and upto 300 feet.
1 in 30	..	For curves of radius greater than 300 feet and upto 400 feet.
1 in 20	.	For curves of radius 500 feet or more.

In this connection it may be mentioned that the original and the revised recommendations of the Technical Sub-Committee were really meant to apply to sharp curves and hair-pin bends met with in hill roads. Mr. Chance's suggestion appears to be quite reasonable and is put up for consideration.

If the Committee agree, they might modify their recommendation to read as follows:—

"The gradient along a curve and for a distance of not less than 100 feet on the up-grade side should be as flat as possible and in no case to exceed the following limits even if it is necessary to increase the gradient for a short distance beyond this length of 100 feet.

Limits of gradient on the up-grade side		Radii of curves
1 in 50	..	200 feet and under.
1 in 40	..	Above 200 feet and upto 300 feet
1 in 30	..	Above 300 feet and upto 500 fe'
1 in 20	.	Above 500 feet.

ANNEX C

At its meeting held on 12th February 1939, the Technical Sub-Committee decided that half a dozen to a dozen sets of particulars of bridges, collected by the Secretary, Indian Roads Congress, be published in 'Indian Roads' in order to ascertain whether there would be any demand for a complete series. Through the courtesy of the Editor, the particulars in respect of half-a-dozen bridges were published in Vol XVI June 1939 issue of "Indian Roads" and the opinions of the readers were invited by the Editor on the proposal to publish the complete information in book from.

There has been no response to that invitation. The matter is, therefore, placed before the Technical Sub-Committee for further decision. (The cost of publishing the particulars which have been collected in respect of about 100 bridges, *without drawings*, in book form will be roughly Rs 400/- for 750 copies. If published, about 500 copies of the book will be distributed free to members and the remaining 250 could perhaps be sold for Rs 2/- each)

ANNEX D

Extract from the Minutes of the Fifteenth meeting of the Council of the Indian Roads Congress held on Friday the 8th December 1939 in the Special train from Poona to Bombay, at 5-45 p.m.

3. *Technical Sub-Committee's Report.*

The Council considered and accepted the report of the Technical Sub-Committee; but as regards the use of primers (item No. 1) Mr. A. Lakshminarayana Rao made it clear that the Council did not mean that a primer must necessarily be used before surface painting a water-bound road. While accepting the recommendation to publish collected particulars of bridges in book form, (item No. 3) the Council expressed the desire that they should be furnished with a statement showing the additional particulars which should be collected in respect of future bridges.

APPENDIX II

TOURS AND OTHER FUNCTIONS HELD DURING THE SIXTH INDIAN ROADS CONGRESS, BOMBAY, DECEMBER 1939.

Thursday, December 7, 1939.

The delegates assembled at the Conference Hall, Electric House, Bombay at 11.00 a.m., when 'Notes on Works to be visited' were introduced and queries relating to these notes were replied to. At 12 noon, the delegates proceeded in taxis to inspect some of the developments of roads and their layout in the city of Bombay.

Prior to 1914, most of the roads in the City were of ordinary water-bound construction with surface crust of metal or sand-stone but without any foundation. On account of increase in traffic, the policy of providing hand-packed rubble foundation was adopted and the roads were watered twice a day to prevent dust nuisance and deterioration of road surface. Further progress was made by using tar of local manufacture at the top, which was helpful in minimising the dust nuisance. This method of treating the roads with tar was found very useful to withstand the disintegration of road surfaces by motor vehicles which were then being introduced in the City. In about the year 1920, asphalt was introduced as a substitute for tar as it was available more or less at the same price as tar and was considered superior in lasting qualities. The methods adopted consisted of surface dressing and grouting by hand pouring. The expenditure incurred on the treatment of roads was met from Revenue which increased from year to year, with the increase in the area of roads and the increase in traffic. This led to the consideration of a scheme consisting of permanent foundation and durable surfaces by financing the expenditure from Loans instead of Revenue. The principle underlying this scheme was that there should not be any additional burden on Revenue to meet the cost of the maintenance of the "Capital Roads"—as they were termed—during the currency of loans. The amount provided for from Revenue in the Budget, every year, included repairs to surfaces, contribution towards a Special Fund for the renewal of surfaces after the expiry of their estimated life and a sinking Fund for the repayment of Loans.

The Corporation have to this date spent more than a crore of rupees by following a wise policy of borrowing and constructing roads with permanent modes of construction. This policy was started in the year 1923 when the cost of repairs and maintenances of roads was Rs.13,87,869. The result of this policy has been that the cost of maintenance of roads is Rs. 5,45,137 to-day. The modes of constructions followed in the programme of road construction are as follows :—

(1) Plant-mixed Asphalt carpets of different types on cement concrete foundations.

(2) Asphalt macadam on concrete foundations,

(3) Sett-stone pavement on cement concrete foundations,

and (4) All-concrete.

It has been found from experience that No. (1) roads are suitable for fast and heavy traffic, No. (2) roads are suitable for medium fast traffic, while Nos (3) and (4) are suitable for heavy and bullock cart traffic. The life of permanent roads is taken at about 15 years for the surface and 30 years for foundation.

The remaining roads not taken up for permanent construction are bitumenised either by resorting to full-grouting or semi-grouting and surface dressing with bitumen. The life of a bituminous road (semi-grouted) is about 5 years, of a full-grouted road 7 years and of a surface dressed road 2 years, depending upon the nature of traffic.

When the road programme was started, the cost of different modes of construction was very high and it has been gradually brought down Before the introduction of Capital Roads programme, the total mileage of roads was 178 The total mileage now is 237 6 which comprises 19 76 miles of asphalt carpets over concrete foundation, 9 4 miles of sett-stone pavement on concrete foundation and about 12 miles of all-concrete roads. Out of the remaining length, the major portion is treated with bitumen by the ordinary method. There is yet a small length of water-bound roads which is gradually being bitumenised, year by year. Unfortunately, when the road programme was taken in hand the carriageways only were considered and footpaths neglected. The work of footpaths was intended to be carried out by providing separate funds in the budget every year. As, however, sufficient funds were not available, the majority of the footpaths in the City are still in a bad condition and unpaved

Formerly, the method of pavement was only Shahabad slabs, but owing to the deterioration and slipperiness thereof by wear, the Corporation have laid down a policy of classifying modes of pavement to suit different localities. The modes of pavement consist of

(1) Blue stone pavement on cement concrete foundations,

(2) Plain or reinforced concrete slab pavement,

and (3) Asphalt macadam without any foundation.

The use of Shahabad pavement has been discontinued as a rule. Besides paving of existing footpaths, the Corporation have adopted a policy of constructing new footpaths on existing roads where no footpaths exist although they are wide enough to take them.

Another improvement effected is the widening of existing roads by acquiring set-backs. Set-back lines have been prescribed for road widening purposes with a view to meet the present demands of traffic. In spite of this, it has been found that a number of roads so widened are inadequate to meet the present needs of growing traffic and in such cases, revised set-back lines have been prescribed wherever possible.

A number of 'bottlenecks' existed on arterial roads causing a lot of congestion of traffic. Steps have been taken to remove the bottlenecks at

Love Grove, Old Parbhadevi Road and Bellasis Bridge, and the works of widening similar bottlenecks at First Marine Street and Bandra Causeway are in hand. Another scheme of removing the bottleneck at Sion has been approved.

For the proper regulation of vehicular traffic at various important junctions, the Corporation have adopted a policy of constructing traffic islands and pedestrian crossings for which separate funds are being allotted every year. A detailed programme of construction of such island has been drawn up and some of them have already been constructed. In addition, a number of pedestrian crossings have been provided at different points in the City for the safety of pedestrians. The Corporation are also considering the feasibility of providing foot-overbridges and subways on important busy roads, such as Queen's Road, the Marine Drive and the Chowpatty. Funds have already been provided for the construction of a foot-overbridge across Queen's Road near its junction with Princess Street.

Another important improvement from traffic point of view is the rounding of corners at various street crossings to improve visibility and easy turning of cars. This is being effected by acquiring lands wherever necessary after prescribing set-back lines at such corners

Owing to growing demands for the safety of traffic, both pedestrian and vehicular, the layout of the main arterial roads has been altered so as to provide dual carriageways on either side of a central verge with pedestrian crossings at suitable points In order to prevent the glare of motor vehicles at night, a box hedge is planted on the central verge. A beautiful drive on the Back Bay Reclamation has recently been completed on the above lines with the construction of the Marine Drive The Hornby Vellard, which has been recently widened, has been constructed on the same lines This policy will be kept in view while constructing new arterial roads or the existing similarly situated roads, wherever opportunity occurs

COLABA ROAD—FROM HENRY ROAD TO KITTRIDGE ROAD

'Colaba Road' is a continuation of 'Colaba Causeway',* which was

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* The mix used in 1923-24 on Colaba Causeway was as follows.--

Binder Course		Wearing Course	
Asphalt (Bitumen 4.5) ..	8.3%	Asphalt (Bitumen) .	12 0%
Sand	23.4%	Sand	69 0%
Stone	68.3%	Filler (Cement) .	19.0%

Asphalt used was fluxed Trinidad Lake asphalt of 16 penetration at 77 degrees F. with 100 grms. weight for 5 seconds

The asphalt was laid at a cost of Rs 8/- per sq. yd and the average cost of maintenance works out to about Rs 0·12 per sq yd. per annum

formerly a water-bound road surface * dressed with asphalt and without any foundation. It was treated with a permanent mode of construction consisting of 3-inch sheet asphalt on 6-inch (1 . 3 : 6) cement concrete foundation in the year 1923-24. Colaba Road which was also of similar construction was omitted from permanent construction then, as it was to be widened on the west side. With the removal of the old Colaba Station, the Railway land became available for being added to the road and consequently its widening was taken in hand. Formerly, there was a single tramway track which was altered to double track after the road was widened. The road carries a fairly good traffic (620 tons per yard width per day). Its permanent construction was taken in hand early this year.

The width of the road varies from 60 feet to 80 feet and the net carriageway on each side, excluding the tram tracks, is 14 feet and 20 feet respectively. Originally, it was proposed to lay sett pavement on 6-inch (1 · 3 : 6) cement concrete foundation on the 14 feet wide carriageway, and 3-inch sheet asphalt on cement concrete foundation (1 : 3 : 6) on the 20 feet carriageway. Sett pavement was selected for the narrow carriageway as it was found by experience that sheet asphalt develops ruts in such positions owing to concentrated traffic. In the meanwhile, the locality was developed as a predominantly residential area and it was, therefore, considered desireable to omit sett pavement, which is usually noisy and, therefore, not liked by the residents, and to use in its stead two-course concrete pavement known as 'Clevecrete", which does not suffer from this drawback.

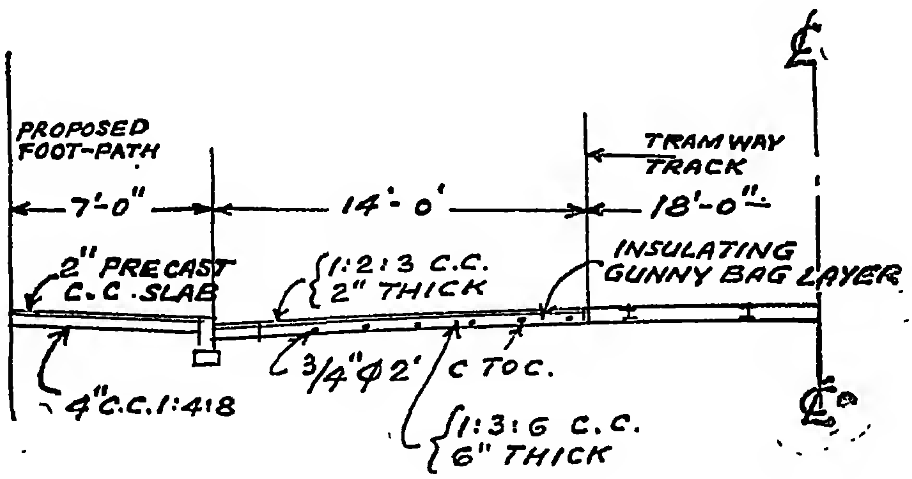
The main advantage of this type of construction is that if the top surface wears out, it can be replaced by similar concrete or asphalt carpet. To enable the removal of the top 2-inch course without disturbing the bottom concrete at the time of renewal, a jute fabric is introduced between the two courses to provide the cleavage plane.

The details of construction of "Clevecrete" are as follows :—

The foundation course of cement concrete 6 inches thick (1 : 3 · 6) consisting of metal, graded from ½ inch to 1½ inch, is laid over well consolidated subgrade Immediately after laying and before setting starts in, a jute fabric ⅛-inch mesh is spread over this course and on it a mix of rich concrete (1 : 2 : 3) 2 inches thick, consisting of metal graded from ¼ inch to ¾ inch and specially washed and screened Mumbra sand, is laid and finished off as in ordinary concrete construction. ¾ inch dowel bars, 4 feet long and 2 feet centres, are provided in the transverse joints of the bottom course.

* Surface dressing with asphalt consisted in painting the road surface with asphalt at the rate of 1/3 to ½ gallon per sq. yd. after first thoroughly cleaning the surface. ½ inch chips were then immediately spread uniformly over the surface at the rate of 4 to 6 c. ft. per 100 sq. ft. Asphalt used was 'Spramex' of 80/100 penetration, rolled at the rate of ½ to 1/3 gallon per sq yd. with a roller of about 10 tons. A seal coat was given to this surface by spreading asphalt over it at the rate of ¼ to 1/3 gallon per sq. yd. and grit of ⅛ inch to ¼ inch was spread over it at the rate of about 2 c. ft per 100 sq ft. Final rolling was done with a 6 to 8 ton roller. The cost of this mode of construction amounted to about Rs 6-4-0 per 100 sq. ft Life about 2 years under light traffic.

Tamping of the two courses was done longitudinally by fixing the transverse joints at 15 feet intervals to get over the difficulty of cross tamping due to the movement of tram-cars. Premoulded filler joints have been used for transverse joints and for longitudinal joints on the side of the tram track. A section of the two-course concrete is given below :—



This work was carried out in May 1939 at a cost of Rs. 22-8-0 per 100 square feet for the foundation course exclusive of excavation and Rs. 19 per 100 square feet for the top course.

The sheet asphalt carpet on the 20 feet wide carriageway was laid in two courses—a $1\frac{3}{4}$-inch binder and a $1\frac{1}{4}$-inch wearing surface The ingredients of the binder and wearing surface consisted of :—

Binder.		Wearing Surface.	
Metal (2 of 1 in. and 1 of $\frac{1}{2}$in.)	69%	Graded sand	75.5%
Sand	26 5%	Filler	13.5%
Asphalt	4 5%	Asphalt	11 0%

Asphalt used was Socony asphalt of 30/40 penetration at 77 degrees Fahrenheit, with 100 grammes weight for 5 seconds. Filler was finely ground trap stone, 95 per cent passing 200 mesh. Sand for the wearing surface was of the following grading :—

30 % passing 80 mesh.

45 % between 80 and 40 mesh.

25 % between 40 and 10 mesh.

As sheet asphalt surfaces have been found to become slippery under fast traffic, the surface was rendered non-skid by spreading a thin uniform layer of ½ inch precoated chips at the time of the final rolling of the wearing carpet The chips were coated with a cut-back asphalt, 3 per cent by weight, and spread hot over the finished sheet asphalt surface at the rate of 4 cubic feet per 100 square feet of area.

The cost of sheet asphalt exclusive of foundations amounted to Rs. 3-12-0 per square yard.

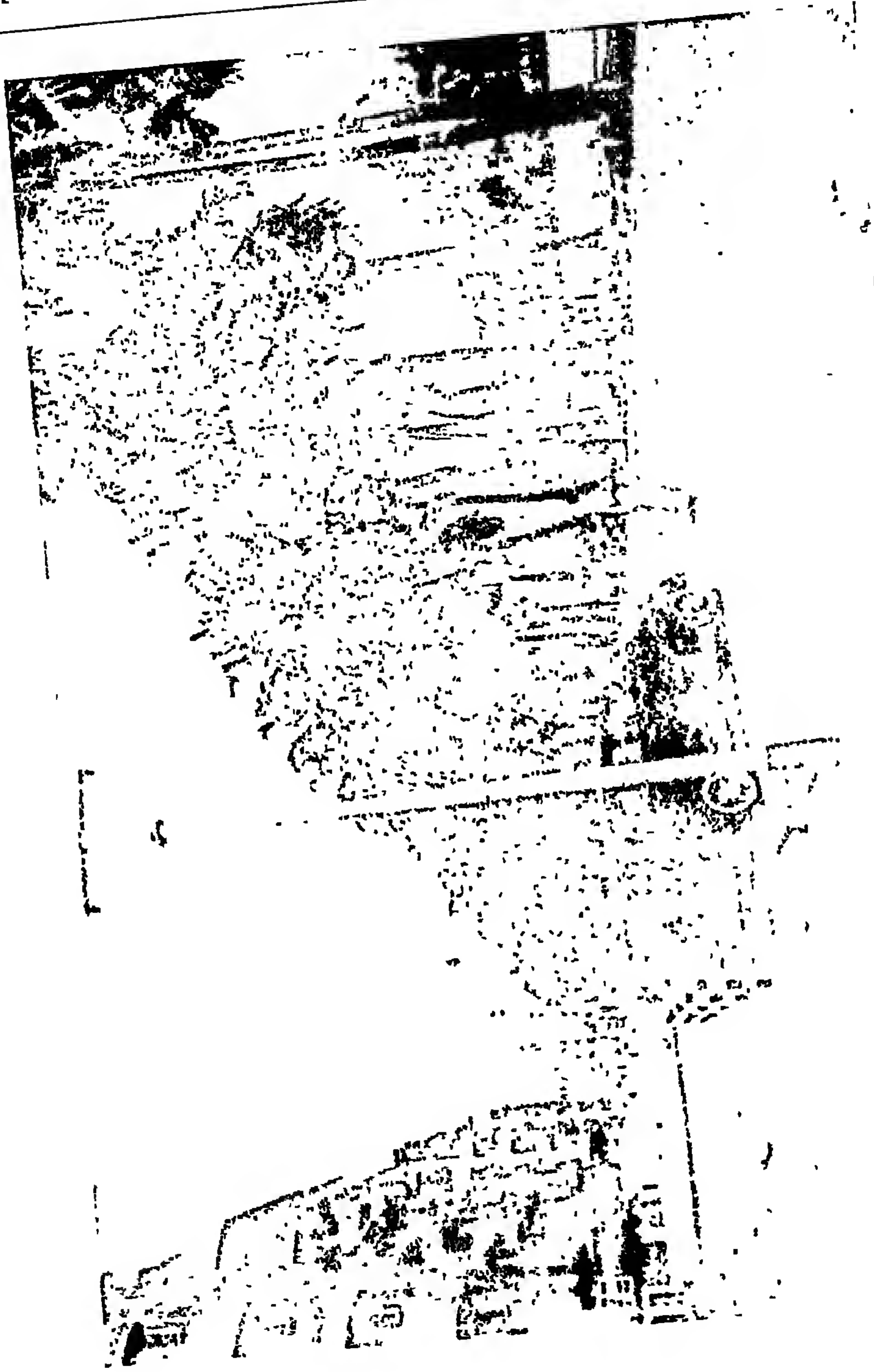
TRAFFIC ISLANDS.

Various methods have been adopted for delineating 'Traffic Islands.' The earlier islands were delineated with ordinary stone kerbs painted black and yellow for visibility. Later on, different types of concrete kerbs and posts were used for the same purpose The use of posts, however, is now being discouraged as there is a tendency on the part of drivers to fight shy of them, resulting in the reduction of the effective carriageway. A drawing showing the types of kerbs or posts used in connection with traffic islands is given on page 30.

The following is the description of the islands visited :—

Locality	Method of construction	Cost Rs.
1. Band Stand, Queen's Road	Sloping kerb	1,727
2. Opposite Army and Navy, Esplanade Road	Semi-circular kerb black and white.	394
3 Junction at Flora Fountain	White and black posts	858
4. Churchgate Station ..	Yellow and black spun concrete posts.	903
5. Junction of Ibrahim Rahimtulla Road and Mahomed Ali Road.	Black and white segmental kerbs.	988

Car parks have been provided inside the islands in the case of the first four as the area is sufficiently large.

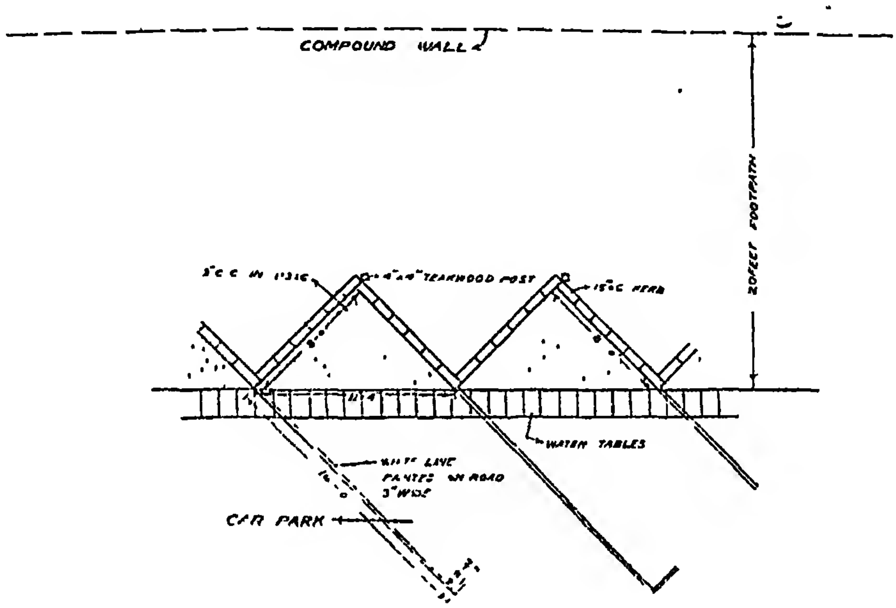


Serrated Car Park Queen's Road, Bombay

(Photo by courtesy of Mr P. A. Kapur)

SERRATED CAR PARK
AND
PRECAST CONCRETE SLAB PAVEMENT.

To enable cars being parked along the kerb in the case of roads which have sufficiently wide carriageways and footpaths, serrated car parks are being constructed abroad A beginning has been made in this City by constructing a serrated car park along the 20 feet footpath of Queen's



Road near Band Stand (*vide* sketch above) The accommodation provided is for 33 cars and the cost of construction amounted to Rs. 768.

On the same footpath,* precast cement concrete slabs, 2 inches thick, have been used A copy of the general specifications observed in their manufacture is given below. The cost of manufacturing such slabs is about Rs 18 per 100 square feet of 61 Nos. The cost of laying a complete pavement, including 3 inches cement concrete (1 . 4 : 8), foundation works out to about Rs. 45 per 100 square feet Footpaths which are not likely to be opened up often, as in the case of Marine Drive, are paved by this method by casting the slabs in situ.

General Specification for Precast Concrete Slabs for footpath pavement.

(1) *Size.*—The slabs should be made of convenient sizes, say 17" × 14" for easy handling.

(2) *Thickness.*—The thickness of the slabs including the top wearing surface shall not be less than 2". The slabs should be lightly reinforced to

* Formerly the paving material used for the pavement of footpaths was Shahabad and blue stone slabs. The latter being costly, the former were used on a large scale. As, however, they were found to become slippery after a long use, their use is being discontinued. Cement concrete slabs 2 inches thick (reinforced or otherwise) have been introduced in their stead as a measure of economy in localities where the use of blue stones is not warranted on account of the nature of traffic

prevent their cracking at the time of transport and also at the time of removal and refixing them when the footpaths are opened for laying services.

The thickness of each slab shall be uniform, all angles shall be true right angles, the edges shall be clean and sharp, and the wearing surface shall be true, out of winding, and free from all excrescences and depressions

On being fractured, the interior of the slabs shall present a clean homogeneous appearance

(3) *Reinforcement.*—Reinforcement shall consist of welded fabric with square mesh 3"×3"×10 B. W. G. or 4"×4"×No. 8 B. W. G. or X.P.M. 6"×3"×$\frac{1}{8}$"×$\frac{1}{8}$". Welded fabric reinforcement will be preferable. The reinforcement shall be placed $\frac{3}{4}$" from the bottom of the slab.

(4) *Concrete.*—The concrete for the slabs and for top wearing surface shall be *put in the moulds in immediate succession to* form a homogeneous mass. The concrete for the slabs shall consist of 1 part of cement and 2 parts of sand and 4 parts of graded stone metal from $\frac{1}{2}$" to 1" in size. The concrete for top wearing surface shall be $\frac{1}{2}$" in thickness and shall consist of 1 part of cement. $1\frac{1}{2}$ parts of sand and $1\frac{1}{2}$ parts of stone chips $\frac{1}{8}$" to $\frac{3}{8}$" in size. In order to make the surface non-slippery, they should be impressed with a suitable design to be approved by the City Engineer.

(5) *Moulds.*—The moulds shall be accurate in size and form and of substantial construction, and shall be maintained in proper form and condition. The internal surfaces shall be of steel or other suitable material, clean and true.

(6) *Mouldings.*—Immediately after the completion of mixing, the material shall be filled into the moulds and consolidated either by pressure, vibration or other effective method, so as to obtain a homogeneous mass. There shall be no disturbance of the material after the initial set has taken place and the slab left in the mould for not less than 12 hours after it is concreted.

(7) *Curing.*—Immediately after. the slabs are removed from the moulds they shall be immersed in a tank of water and left there for about two weeks. When this is not convenient or practicable, the slabs may be removed from the tanks after a week and kept covered with sacking which should be kept wet for another week. These slabs may then be stacked in a shady place. They should not be transported for use in works before they are three weeks old. The longer they are kept the better

(8) *Laying.*—The slabs shall be laid on a layer of about $\frac{1}{4}$" sand on a bed of either 3" cement concrete 1 : 4 : 8 or 4" lime concrete.

At 1.00 p.m., the delegates returned to their lodgings.

The delegates re-assembled at the stand for delegates' buses on traffic island near Church Gate Street Railway Station at 2.30. p.m., and proceeded to visit the Marine Drive in the Back Bay reclamation scheme. and the Sea Wall.

SEA WALL

A sea wall 25,396 feet or 4.81 miles long of varying cross sections, as detailed in the drawings pages 38 to 41, has been constructed except for a gap of 1,850 feet. It encloses an area of 1,125 acres from the foreshore of the Back Bay. The wall mainly serves the purpose of protecting the filling used for reclamation from the sea.

The first section, 3,800 feet long, from the south end of Chowpatty, usually known as the Kennedy Sea Face or old sea wall, is founded on Reinforced Cement Concrete piles and is a masonry wall with heavy block-in-course masonry and cement concrete backing. The new sea wall, in continuation of the old sea wall, measuring 7,980 feet, is constructed on a rubble mound. The section of the concrete wall is 16′×8′. The sea wall from the Colaba end, measuring 11,714 feet, is also founded on a rubble mound except for a length of 2,000 feet where it is built directly over the rocky bed of the sea. This wall varies from 12′×5′ to 12′×12′. The sea wall along the Marine Drive has been surmounted by a Reinforced Cement Concrete parapet wall stepped on the land side and with a bull nose on the sea side.

MARINE DRIVE

The Marine Drive along the sea shore, in Blocks I and II of the Back Bay Reclamation Scheme, measuring nearly two miles, is a fine modern and very popular thoroughfare in Bombay and has been constructed on up-to-date principles. It has a total width of 140 feet apportioned into different sections to suit the requirements of both vehicular and pedestrian traffic A detailed cross section of the road is reproduced on page 42

This road is constructed on land reclaimed from the sea some six years ago. The sub-grade consisting of an approximate filling of 18 feet deep of dredged materials, *viz.* silt and sand and about 2 feet of murum topping, was well consolidated with 15-ton roller and any soft spots noticed while rolling were made good to a depth varying from 2 feet to 3 feet with good building debris. The western carriageway of the Marine Drive from Chowpatty to Churchgate Street Extension has a 7½ inches uniform thickness of 1 : 3 : 6 cement concrete foundation and 3 inches thick sheet asphalt surfacing and the remaining length and eastern carriageway is an all-concrete road of 1 : 2 : 4 mix and 9″—6″—6″—9″ section. With the heavy traffic, about 10 motor cars every minute, the sheet asphalt was getting polished and becoming very smooth. Such a surface with lubricating oil dripping on to it from the passing vehicles was apprehended to become slippery and dangerous. Hence a subsequent treatment of asphalt painting blinded with ⅜ inch to ½ inch stone chips was undertaken to render the surface rough and free from skidding mentioned above. Subsequently a cheaper type of road was considered and all-concrete road construction was decided upon. The details of construction are as under :—

(*a*) *Asphalt surfaced road 40 feet wide (western carriageway).*

(Order of construction from the bottom.)

(1) 3 inches coal clinkers spread uniformly and light rolled.

(2) 7½ inches uniform thickness of 1 : 3 : 6 cement concrete foundation reinforced with B. R. C. Fabric No. 9.

(3) 3 inches thick, plant mixed, sheet asphalt consisting of $1\frac{3}{4}$ inch thick base coat and $1\frac{1}{4}$ inch thick seal coat—the aggregate and asphalt being proportioned by weight and mixed hot in a stationary asphalt mixing plant. (Detailed specifications are given on page 37).

(4) Surface painted with asphalt and blinded with $\frac{3}{8}$ inch to $\frac{1}{2}$ inch stone chips to make the surface non-skiddy. Its cost was Rs. 2-4-0 per 100 squre feet.

(*b*) *Reinforced cement concrete road 40 feet wide* (9″—6″—6″—9″ *section*)

(Eastern carriageway from Chowpatty upto Churchgate street extension and full width from that road to end of Block II).

(1) Road lining paper—one layer.

(2) One course cement concrete road of required section with B. R. C Fabric No. 9 reinforcement.

(*c*) *Cost.*—The detailed specifications are given on page 37. The sheet asphalt surfaced road cost about Rs. 90 per 100 square feet and the cement concrete road about Rs. 60 per 100 square feet

(*d*) *Camber.*—A flat camber of 1 in 80 has been adopted for both the types of road surfaces with a view to affording maximum comfort over all portions in the cross section of the road.

(*e*) *Roadway.*—There are two independent carriageways 40 feet wide each for the North and South bound traffic with a central refuge island 5 feet wide containing a green box hedge 3 feet 6 inches wide and 4 feet high separating the two carriageways. The hedge serves (*a*) to prevent the pedestrians crossing the road at places other than those that have been specially provided, (*b*) to prevent the glare of the head-lights of motor cars proceeding in opposite directions, and (*c*) to provide a soft verdure to the eye and an aesthetic and pleasing appearance to the road.

(*f*) *Footpaths.*—The width of the footpath on the sea or West side is 45 feet including the thickness of the parapet wall and that on the land or East side is 10 feet. This width along the foreshore provides ample safe space for thousands of the general public, who resort to it daily for recreation and enjoying the sea breeze. The stepped parapet wall provides extensive sitting accommodation for the young and aged when they feel tired. In this foot-path there are three types of pavements, (1) blue stone pavement 10 feet wide close to the kerb line, (2) Precast Reinforced Cement Concrete slab on cement concrete foundation and sand cushioning six feet in width to admit of future operation for laying utility services and (3) plain cement concrete in situ pavement 26 feet wide.

The blue stone pavement, though rough, was expected to last three times as long as a concrete pavement and hence was originally adopted to a width of 10 feet. Subsequently with a view to economising first cost and providing a smoother pavement to which the public could easily be induced to adhere, cement concrete pavement attractive in appearance, rendered non-slippery by imprinting indented squares, has been provided.

This concrete pavement has proved successful and is now being adopted generally in the City by the Corporation in residential areas. The precast slab section has been laid so as to be easily removeable and replaceable while accommodating any further service mains.

Of the two types of cement concrete pavements, the one laid in situ appears to be more durable than the precast slab. It is, however, too early to say a final word in the matter. The cost of the concrete pavement is about Rs 33 per 100 square feet as against Rs. 65 per 100 square feet of blue stone pavement.

(g) Kerbs.— To improve the facilities for motoring public, cement concrete chamferred kerbs with alternately black and yellow coloured plaster have been provided along the central refuge island. Various other warning devices such as Belisha beacons, yellow herring bone type lines, caution signals, 'No right turn' sign boards, electrically operated signals with green, red and amber indications, traffic round-abouts with "Keep Left" lamps, white turtle etc are to be provided. At present there are two traffic round-abouts, three vehicular crossings* and six pedestrian crossings and provision of a few more pedestrian and vehicular crossings is under consideration.

(h) Lighting —It has been found to be cheaper both in first cost and running charges to light the streets with gas lamps instead of electric lamps and hence the former have been adopted throughout the scheme.

(i) Drainage.—Storm-water drains of adequate sizes have been laid to ensure freedom from accumulation of water even during the heaviest showers at the time of the highest tide. These drains have outfalls into the sea at suitable places. Water entrances, single or double, as the case may be, with cast iron screens of closable top gratings have been provided at suitable spacings. The western carriageway along the new sea wall is drained through 12 inches diameter pipe outlets with flap valves and the eastern carriageway and the western carriageway in front of old sea wall are drained to suitable minor storm-water drains connected to the major drains

(j) Sewer drains.—Glazed stoneware pipe drains, gravitating to the inlet manhole of Shone's Ejector Stations or to an existing corporation drain have been provided with accessories such as vent-shafts, manholes and plot connections.

(k) The *present condition* of the Marine Drive is good and no subsequent treatment to the surface since its construction in 1937 has been found necessary. Minor cracks have occurred in concrete road at corners of manhole frames. This defect is intended to be avoided in future by providing necessary temperature reinforcement.

* Details of Pedestrian Crossings are given in the plan on page 43.

DETAILED SPECIFICATIONS

FOR

3-inch thick sheet asphalt with 1¼-inch thick binder course and 1¾ inch thick wearing surface or seal coat, used in the Marine Drive are as follows :—

(1) *Binder Course*—(Materials for 100 square feet)

(i) Coarse aggregate (trap rock) { 1 inch metal—12 cubic feet. ½ inch metal— 6 cubic feet.

(ii) Fine aggregate .. .. Mumbra or black river sand—6½ cubic feet.

(iii) Socony asphalt steam refined grade; 30 to 40 penetration. } 115 pounds or 11.5 gallons.

(2) *Seal Coat*—

(i) Fine aggregate consisting of 3 parts of fine white (Juhu) sand and one part of Mumbra or black river sand .. ... 10 cubic feet

(ii) Filler—finely ground trap stone 95 per cent passing a 200 mesh screen .. ... 1.8 cubic feet.

(iii) Socony asphalt for 30 to 40 penetration.. 147 pounds.

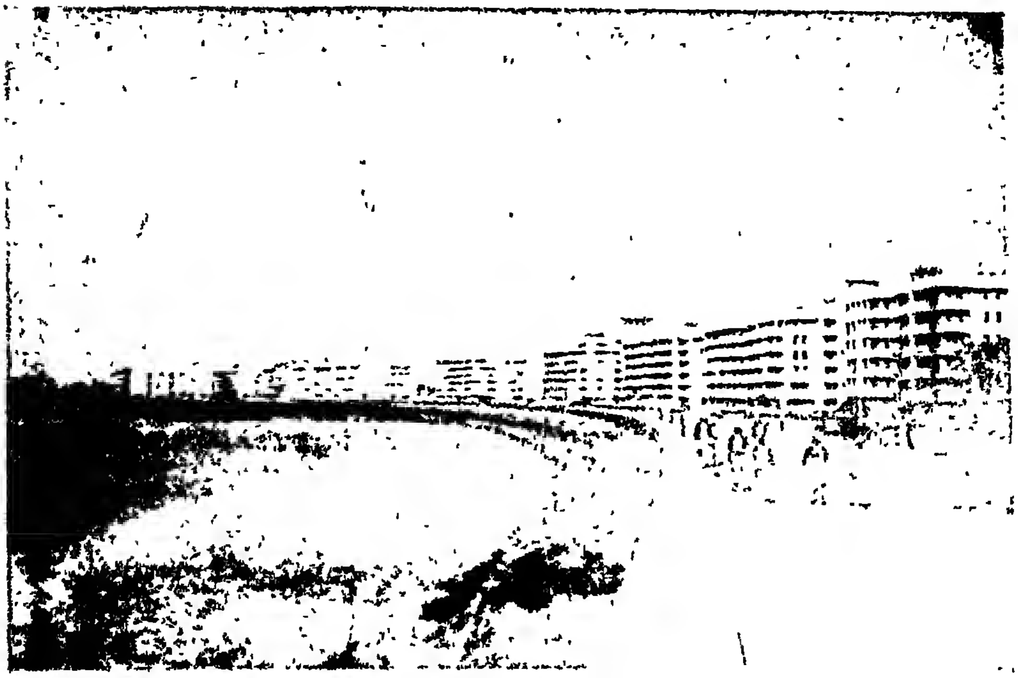
(3) *After treatment to make the surface rough*—

12 pounds 30 to 40 penetration asphalt dissolved in 1 33 pounds of kerosene oil was used to paint the surface and binded with 3 cubic feet of ¾ inch stone chips

*Rate**—Rs. 3-10-0 per square yard or Rs. 40-4-0 per 100 square feet.

N.B.—(*a*) The materials are proportioned by actual weight but the above quantities have been worked out per 100 square feet to facilitate comparison.

(*b*) * This work was carried out by the Bombay Municipality on behalf of Government at the rate mentioned above.



The Sea Wall along Marine Drive, Bombay

The Marine Drive, a very popular drive in Bombay.

(Photos by courtesy of Mr. P. V. Rajan)

The delegates then inspected certain roads in Bombay City.

FORT STREET—This was reconstructed with a permanent mode of construction with 3 inches sheet asphalt (estimated life 15 years) on 6 inches (1 : 3 : 6) cement concrete foundation in the year 1925-26. The mix used then was as follows :—

Binder Course		Surface Course	
Metal (2 of 1 inch and 1 of ½ inch size)	73.0%	Graded sand	72.0%
Black sand	18.4%	Filler (Portland cement)	16.9%
Asphalt	8.6%	Asphalt	11.1%

Fluxed Trinidad Lake Asphalt of 16 penetration at 77 degrees Fahrenheit with 100 grammes weight for 5 seconds was used.

	Rs. a. p.
Cost of foundations	25 11 0 per 100 square feet.
Cost of sheet asphalt	7 0 0 per square yard.
Average cost of maintenance per annum	Re 0.17 per square yard.

As large stretches of this road have gone very bad, its carpet is being renewed wherever necessary. The mix for the renewal carpet consists of :—

Binder Course		Wearing Surface	
Metal (2 of 1 inch and 1 of ½ inch size)	69.0%	Graded sand	75.5%
Black sand	26.5%	Filler (stone dust) ..	13.5%
Asphalt	4.5%	Asphalt	11.0%

Asphalt used is Mexphalte of 30-40 penetration at 77 degrees Fahrenheit with 100 grammes weight for 5 seconds

In the old carpet, asphalt of 16 penetration was used as it was then considered suitable for such work. Several roads in the City have also been treated with sheet asphalt of such low penetration The experience has, however, shown that such carpets developed cracks. With a view to prevent cracking, asphalt having a penetration of 30 to 40 is in use for the last 8 years.

The sheet asphalt carpet is laid as follows :-

The ingredients of the asphalt carpet are mixed at the Asphalt Plant situated at Worli, described on page 40 at a temperature of 315 degrees Fahrenheit and conveyed to the site of works in self-tipping lorries covered over with tarpauline The temperature of the mix drops down to about 300 degrees Fahrenheit by the time it reaches the site of work The binder course is spread hot to a thickness of a little more than the required thickness of 1¾ inches and immediately rolled by Tandem roller of 6 to 8 tons of the instantaneous reverse mechanism type to enable rolling being done in all directions without jerks and to obtain a uniform surface free from impressions. As the Municipal Tandem rollers are of the steam-driven type, two are used at one time to ensure continuous rolling without stop, as the mixture must be consolidated to a finish while hot. These rollers are also equipped with special water sprinkling arrangement to prevent the mixture from sticking to the wheels

The wearing carpet (which consists of fine materials only) is then uniformly spread to a thickness of slightly more than 1¼ inches and rolled down by a Tandem roller when the temperature of the mix drops down

to about 200 degrees Fahrenheit to prevent sudden chilling and peeling out of the top surface which is common with high temperature and fine materials.

The cost of the present work is Rs. 3-12-0 per square yard.

ARGYLE ROAD—This is an example of an all-concrete road carrying very heavy mixed traffic of bullock carts and lorries. A stretch of this road about 1,800 feet in length from Elphinstone Bridge to Musjid Bridge was laid in 1931 with a uniform thickness of 8 inches concrete (1 : 2 : 3) with premoulded asphalt fillers between transverse and longitudinal joints. Dowel bars ¾ inch in diameter, 4 feet long and 2 feet centres have been used at the junctions of cross streets The coarse aggregate used varied from ¼ inch to 2¼ inch in size. Average cost of concrete per 100 square feet was Rs. 61.

During the first 5 years after the construction of the road, practically no repairs were required to be carried out except minor repairs to joints. The average cost of maintenance per 100 square feet since its construction works out to Rs. 0.16 per square yard per annum.

During the past few years it has been observed that the concrete has developed some cracks and has worn out at some joints. At places, small pot-holes are also noticed. Otherwise, it is in a fairly good condition. Considering the heavy traffic on this road it has stood well.

CHINCH BUNDER ROAD—This is an example where sett stone pavement is being laid on 6 inches cement concrete (1 : 3 : 6) foundation in continuation of the stretch already laid † in the year 1933-34 with the same mode of construction. The cost of sett stone pavement then was Rs. 51 per 100 square feet and that of foundation exclusive of excavation was Rs. 33 per 100 square feet.

The existing surface of the road under construction is a waterbound road surface dressed with asphalt with a camber of 1 in 25 which will be flattened to 1 in 50 in reconstruction The present cost of this mode of pavement is Rs. 50 per 100 square feet and the cost of foundation without excavation is Rs. 27 per 100 square feet.

LAMINGTON ROAD—The portion of Lamington Road from Bellasis Road to Club Road was taken up for permanent mode of construction with sheet asphalt of the following mix on 6 inches cement concrete foundation 1 : 3 : 6 in the year 1931-32 .—

Binder Course.		Wearing Course	
Metal (2 parts 1 inch and 1 part of ½ inch)	69.0%	Graded sand . .	78.0%
Black sand	26.5%	Filler (stone dust)	11.0%
Asphalt of 20/30 penetration	4.5%	Asphalt	11.0%

Cost of carpet .. .. .. Rs 1-9-0 per sq. yard.
Cost of cement concrete foundation .. Rs 30-0-0 per 100 sq. ft

* Argyle Road extends from Elphinstone Bridge to Carnac Bridge, a distance of about half a mile. It is a main road and serves the Dana Bunder locality where the traffic consists of bullock carts and lorries. Originally, it was a water-bound road on 10 inches of rubble foundation.

† The sett pavement constructed in 1933-34 has stood the traffic well. It has however, worn uneven at certain places due perhaps to variation in the quality of stone setts which are obtained from local quarries.

No expenditure was incurred on maintenance for the first 4 years. It was, however, found necessary to repair cracks and pot-holes as they developed in the succeeding years. The average cost of filling-in the cracks, repairing pot-holes and giving a paint coat over the cracks works to about Rs. 0.09 per square yard per annum.

In addition to cracking, the surface of the road has also been found to wear out unevenly at a number of places. It is not, however, considered necessary to renew the whole carpet as the binder (bottom) course has not deteriorated and the foundations are also in a good condition. To enable the top wearing course being removed from the binder course without disturbance, a special Heater* (purchased in the year 1938 at a cost of Rs. 4,254) is employed, which consists of (1) Power Unit, (2) Air Compressor, (3) Light Diesel oil storage tank, (4) Heating hood with the burner and oil and air pipes leading to it, (5) Fan for inducing the draft and the duct leading therefrom to the hood, *vide* page 47.

FERGUSSON ROAD —This is another example where some portions of the road have been treated with 'Clevecrete' and 1½ inches to 2 inches gunite surface over the usual 6 inches concrete foundations as an experimental measure. The major portion of this road has been treated with 3 inches sheet asphalt on 6 inches cement concrete (1 : 3 : 6) foundations with the same mix as that adopted on Colaba Road except that the percentage of filler was slightly more. Its present width is 40 feet, and its ultimate width is going to be 60 feet while a small portion at its eastern end will have a width of 90 feet. This work was carried out in 1936-37.

The portion treated with 'Clevecrete' has stood the traffic well, with the exception of the portions at the corners of bays which have cracked, and there are a few cracks also on the surface. The cost of foundation without excavation was about Rs 27-8-0 per 100 square feet and the cost of laying the top 2 inches of carpet was about Rs. 11-8-0 per 100 square feet exclusive of the cost of cement which was supplied free by the Concrete Association of India.

The gunite surface was laid under pressure with a mixture of 1 part of cement to 2 to 3 parts of washed Mumbra sand to a thickness of 1½ inches to 2 inches without any joint on the 6 inches cement concrete foundation (1 : 3 : 6).

To avoid possibility of cracking, the gunite surface was reinforced by a B. R. C. fabric, 3/16 inch wires in 6 inches squares, tied to ⅛ inch dowel bars, 3 inches long, embedded in the concrete protruding ½ inch above the bed at 3 feet centres.

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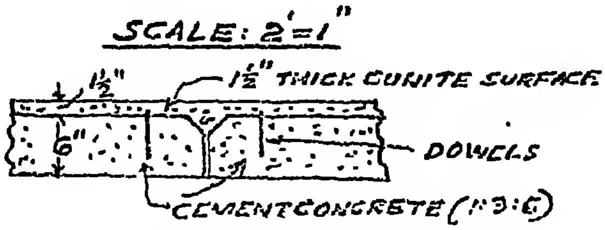
* Prior to the use of the Heater, cracks were filled with a premix mastic of 20 per cent. asphalt, 20 per cent. filler and 60 per cent. sand after getting them thoroughly raked and cleansed. The surface was then covered over with a mixture consisting of two parts of liquid fuel and one part of hot asphalt. It was allowed to soak in for 48 hours. This served to soften the surface and allowed a proper bondage to the seal coat. A paint coat of 80/100 hot asphalt was then applied and blinded with fine grit and then rolled. The cost of this method was about Rs. 2-8-0 per 100 square feet. An example of this method of treatment was seen on Worli Road on the way to the new Asphalt Plant.

To guard against natural weakness of joints in the concrete foundations, the gunite was thickened at the joints by cutting a V-shaped groove as shown in the sketch below.



CROSS SECTION OF ROAD

The guniting was done by Messrs. John Fleming & Co., who are the sole agents for the cement gun, at a cost of Rs 3-7-0 per square yard exclusive of the cost of cement and sand which are supplied by the Municipality. The overall cost works out to Rs. 3-15-0 per square yard. It was intended to lay a stretch of about 600 feet in length but after laying a length of 102 feet, further work was discontinued on the recommendation of Messrs. John Fleming and Co., as they found difficulty in eliminating the wavy nature of the surface and thought it advisable to watch the result of the work already carried out before recommending its further use.

This surface which was slightly wavy when laid, further developed slight cracks and top surface is peeling off at places.

The delegates then visited 'the road plant and machinery' of the Bombay Municipality, at Worli

STONE CRUSHING PLANTS.

There are two types of stone crushing plants, one is capable of producing all sizes of metal *i. e.*, 1½ inches, 1 inch, ½ inch and grit and dust and the other is meant to produce ½ inch, ¼ inch grit and dust. The former is located at Worli and the latter at Sewree.

Plant at Worli consists of (*a*) Primary Breaker (*b*) revolving screen with reject cone arrangement. Breaker is of the Jaw-type with 16″×9″ mouth. Of the two jaws, one is fixed while the other is moveable and is worked by an eccentric and compound lever arrangement. Eccentric lever is driven by means of a pully at 275 revolutions per minute. Jaws are of renewable special hard manganese steel and the distance between the two can be adjusted to suit the size of the metal to be turned out.

Rubble of not more than 10 inches in size in any direction is used for breaking into metal Crushed material is discharged from the breaker into a revolving screen. This screen has holes arranged in a screw like fashion, so that material passes along the screen without crossing itself. In the middle of the screen, a reject cone is attached to collect oversize metal which is collected and elevated by an elevator and put back

into the breaker by means of a chute. The screen being punched for the required size of metal, it turns out different sizes of metal separately, all over-size pieces being automatically returned to the breaker by the reject cone arrangement.

Plant at Sewree is of a slightly different type than the one at Worli. This consists of a breaker as already described with a raft-wheel and a granulator. Raft-wheel consists of a screen attached to its rim, and buckets on the inside plate. These buckets serve the purpose of elevating the material received from the breaker and feeding into granulator, while the screen does its own work. Granulator consists of two 18-inch diameter rolls of hard manganese steel, moving in opposite directions. Distance between the two is adjustable according to the size of metal desired. Output from the granulator is discharged into the raft-wheel screen. Finished product from the screen is passed on a horizontal screen to remove dust and 1/8 inch size.

Along with metal, about 13 per cent dust is produced. To minimise this and to produce a more cubical size of stone, granulator is substituted by a kubit breaker. It is a slow speed, fixed hammer machine, relying solely on the impact for the reduction of the size of stone. No crushing and grinding action is involved in its operation, the stone being broken by throwing it against fixed hammers which produce a more cubical product. However, there is no appreciable reduction in the production of dust with the kubit but the size of the product is more cubical.

A dust extraction plant has been erected at Sewree Crushers. This consists of a duct line, suction fan coupled with an electric motor and textile filter for collecting dust. Fan has a capacity of sucking 10,000 cubic feet of air per minute at 960 revolutions per minute. It is coupled direct with 17.5 Horse Power electric motor. Sucked air and dust is delivered into textile filters, which allow pure air to blow out, leaving dust to settle down by gravity through conical chutes into bags.

Road Heater.

With the sheet asphalt surfaces, the renewal of whole surface is costly. If only the top surface is removed and relaid, the cost is considerably reduced. A road heater is, therefore, utilised to do the work of heating and removing the top portion of the road.

The road heater consists of (1) Power Unit, (2) Air Compressor. (3) Light diesel oil storage tank, (4) Heating hood with the Burner, and oil and air pipes leading to it, (5) Fan for inducing the draft and the duct leading therefrom to the hood.

Power Unit consists of a Lister Petrol Engine 1½ B.H.P. It is meant for driving the air compressor and the fan for inducing the draft.

Air compressor is meant to supply compressed air to the oil tank and the burner. Oil is forced to the burner from the tank by the compressed air. Only light diesel oil is used in the burner. The fan is provided to force draft to hood so as to regulate the amount of heat given by the flame.

Heating hood is of a conical shape with a rectangular area 4 feet 4 inches by 4 feet 4 inches at the bottom, where it comes in contact with road surface. Burner is fed by two pipes, one of oil and the other of compressed air. It starts just like a stove by heating an open flame with working pressure of the compressed air of 5 pounds per square inch. Regulation of heat is partly done by regulating the supply of oil by a valve and partly by a butter-fly valve in the duct line from the fan to the hood. The former increases or decreases the amount of heat generated by the burner and the latter regulates the intensity of the heating gases. If the butter-fly valve is fully closed, no air passes on to the hood and the burning flame directly comes into contact with the surface to be heated. On opening the valve, flame is diluted till only hot air comes in contact with road surface.

ASPHALT PLANT.

The first "Iroquois" type Asphalt Plant which was purchased at a cost of Rs. 98,000 in the year 1921-22 has run out its useful life. This plant is still working at Love Grove and considerable transport charges are required to be incurred in the transport of metal to the plant from the Municipal Crushers* situated at a distance of about a mile away. A new plant, which is similar to the existing type, has now been purchased at a cost of Rs. 65,222 from Messrs. Heatly and Gresham Ltd. and erected on a new site at Worli where the new Stone Crushers are also erected. The rubble required for crushing is also in close proximity to this site.

The new asphalt plant consists of the following main sections :—(1) Boiler, (2) Engine, (3) Cold Elevator, (4) The Drying Drum, (5) Hot Elevator, (6) The Screen and Storage Bin, (7) The Weigh-Bridge, (8) The Asphalt-Melting Tanks, (9) Air Compressor and Bitumen Lifter, (10) The Mixer, (11) Dust Extraction Plant.

(1) *Boiler* :—It is a 42 horse power locomotive type one, with a working pressure of 150 pounds per square inch and the boiler rating of 1,042 square feet.

(2) *Engine* :—It is a single cylinder non-condensing high speed enclosed type steam-engine of 40 brake Horse Power.

(3) *The Cold Elevator* :—Elevator is of the bucket and chain type. It raises and discharges the cold aggregate into the drying drum through a chute.

* The new Crushers at Worli consist of (*a*) Primary Breaker, (*b*) Revolving Screen with reject cone arrangement Breaker is of the Jaw-type with 16 inches to 9 inches mouth. Of the two jaws one is fixed while the other is movable and is worked by an eccentric and compound lever arrangement. Eccentric lever is driven by means of a pulley at 275 revolutions per minute. Jaws are of renewable special hard manganese steel and the distance between the two can be adjusted to suit the size of the metal to be turned out.

Rubble of not more than 10 inches in size in any direction is used for breaking into metal. Crushed material is discharged from the breaker into a revolving screen. This screen has holes arranged in a screw like fashion. So that material passes along the screen without crossing itself. In the middle of the screen a reject cone is attached to collect oversize metal which is collected and elevated by an elevator and put back into the breaker by means of a chute. The screen being punched for the required size of metal, it turns out different sizes of metal separately all oversize being automatically returned to the breaker by the reject cone arrangement.

(4) *The Drying Drum* :—The cold aggregate passes through the revolving drying drum, which has channel flights inside for raising and spilling the material. The drum is heated by the fuel oil burners fed from an oil tank on the top of the drum. The hot gases pass first round the drum, then through it and finally discharge through the sucton fan of the dust extractor to the chimney.

(5) *Elevator* :—It lifts the hot aggregate from the drying drum to the screen at the top. This is of the same type as the cold elevator, except that it is encased by steel plates to prevent loss of heat and works faster.

(6) *The Screen and Storage Bin* :—This consists of a revolving screen fitted with seven plates with holes punched according to the grading of the aggregate required.

Storage Bin or Hopper :—The hot aggregate after it is screened discharges into a hopper which has two compartments, one for the saud, and the other for metal, each corresponds with the sections of screen above. These compartmants are fitted with sliding doors and hand levers for the discharge and control of the aggregate. They are arranged in such a position as to allow the material to flow direct into a fixed measuring box situated beneath the hopper and over the mixer box.

(7) *The Weigh-Bridge* :—It is of the suspended type, and has four beams for weighing separately one after the other tare weight of the bin, and three different aggregates. Sliding indicator are attached to beams to adjust the position according to the weights required.

(8) *The Asphalt-Melting Tanks* :—There are two melting tanks with a capacity of about 2,000 gallons each. This is sufficient for one full day's work.

(9) *Air Compresser and Bitumen Lifter* :—In order to lift the melted asphalt to the mixing platform a pneumatic bitumen lifter is provided. This consists of a steam-jacketted closed cylindrical reservoir. Melted asphalt through a non-return valve flows into this by gravity. By allowing compressed air at 25 pounds per square inch into the lifter, asphalt is forced up the delivery pipe. Air compressor is capable of compressing air upto about 100 pounds per square inch to lift heavier natural asphalt, and is provided with a compressed air reservoir.

10) *Mixer* :—It is in the form of a box open at the top and has a sliding door at the bottom. Mixer box is provided with a steam-jacket to keep the contents at a uniformly high temperature throughout the process. Inside of the box is provided with renewable special wearing hard manganese steel liners. For mixing, two parallel shafts running in opposite directions are provided with mixer blades of

renewable manganese steel. Mixer shafts run at 6 revolutions per minute and capacity of the box is 800 pounds per batch.

(II) *Dust Extractor Plant*:—It consists of duct line of 18 inches diameter taken from the heating furnace to a suction fan of 18 inches diameter running at 960 revolutions per minute. From the duct the dust is collected by a gradual settlement through a special downward flow spiral passage, volatile gases passing into the chimney above.

Method of laying Asphalt mix.

The mixture heated to about 315 degrees Fahrenheit is conveyed to the site by means of tipping lorries of 4 tons capacity. It takes a lorry about 20 to 30 minutes to reach the spot. When the mixture is unloaded on the job, it is evenly spread over the surface with rakes and shovels to a depth of about 25 per cent greater than the required finish surface to allow for consolidation by rolling.

Immediately the mixture has been spread and sufficiently cooled, it is rolled with a roller of 8 tons capacity. This is followed by rolling at right angles to the direction of road and finally finished by rolling along the length of the roadway.

An area of 500 square yards, 3 inches thick is laid and rolled complete in a day. Traffic is not allowed on a newly laid surface until it is properly hardened.

Road Rollers for Hot Asphalt works.

For rolling hot mixed asphalt materials, it is necessary to have a special type of roller. Ordinary three wheel roller is not suitable for the purpose, as the distribution of the weight of the roller is such that the pressure intensity per linear inch on the back wheel is nearly double that on the front. This type of roller, therefore, leaves heavy wheel marks on the road even with the overlapping of the front wheel on the back wheels.

To avoid formation of depressions on account of the roller taking an appreciable time to reverse, it is essential to have an instantaneous reverse action. Freedom from vibrations and smoothness in running is also desirable for obvious reasons. For quick operation and avoiding strain on the driver, due to continuous working on hot asphalt, it is necessary to have the steering of the roller actuated by power. To prevent sticking of hot materials to rolls, it is desirable to have sprinkler arrangement to keep them wet. Spring operated adjustable scrapers help to remove any foreign material sticking to rolls. Two wheel tandem roller is eminently suited to comply with these requirements and so far this is the only roller used for the purpose. Further quick rolling of curves, junctions and corners is difficult with a wide three wheel roller. Tandem roller with a narrow width has been found to be handy, convenient and efficient for this purpose.

Usually two rollers, one of five tons and the other of eight tons, are used simultaneously on the work. The lighter one is used for initial

rolling and the heavier for finishing work. Both the rollers are similar in design. Description of an eight ton roller only is therefore given, being of special interest.

Steam is generated in a vertical tubular boiler at a working pressure of 140 pounds per square inch. Engine is of a double cylinder' reversible, powerful, non-condensing, slow-speed, slide valve type eliminating the use of governor. Speed is regulated only by the steam valve; it can, therefore, work much faster than the three wheeler. Crankshaft of the engine is connected to a bevel pinion, which drives the back roll. Reversing is done by a lever, which changes the position of the eccentric; steering is of the positive worm, quadrant type, worked by a small separate steam engine or direct by hand. Driving roll is hollow and can be filled with water ballast to increase the weight. There is a water sprinkler on the back roller. The rolls are machined with edges rounded for smooth rolling and preventing creases in the pavement. They are 48 inches wide and fitted with adjustable spring operated scrapers. The maximum pressure it can exert is 275 pounds per linear inch.

The delegates returned to their lodgings at 17.00 p. m.

Friday, December 8, 1939.

The delegates assembled at Victoria Terminus (G. I. P. Ry.) Station and left in a special train arriving Poona at 10.00 a.m. Buses were waiting outside the railway station and the delegates proceeded in these to visit the BOMBAY-POONA ROAD.

This road joins the capital of the Bombay Presidency with the monsoon Headquarters of Government and had till quite lately a water-bound macadam surface throughout. Since the advent of motor vehicles, the public has considered the advantages of motor transport both for goods and passenger traffic over Railway transport on this particular road and it has become one of the most heavily trafficked roads in the Presidency, with the result that the original water-bound surface was found to be rapidly deteriorating and requiring too frequent renewals and even after providing for them, the dust nuisance and the pot-holed surface often forme d a serious danger to health and to traffic. Some lengths neare Poona, Bombay and other towns in between were, therefore, moderniser with various types of experimental bituminous treatments, but after somd experience, it was found that a concrete surface was best suited for the increasing traffic on this road and is now proposed to be provided throughe out the length—except for such portions as have been previously-modernised with tar or bituminous treatment.

Where the bullock cart traffic is heavy near Poona and its suburbs, the type adopted for modernisation is what is called in the following notes "Conphalt", this type having a central asphalted strip for fast motor traffic and two concreted sides each $7\frac{1}{2}$ feet in width for the use of bullock cart and other slow moving traffic. The advantage of this type of surface is that the bullocks prefer to travel over the concrete side widths and thus leave the central asphalted strip for fast moving traffic.

M. 111 F. 5½ (OPPOSITE COLLEGE OF ENGINEERING, POONA.)

1½ INCHES SEMI-GROUT ASPHALT WITH SOCONY 101-E ASPHALT AT 9 GALLONS PER 100 SQUARE FEET. This was laid for a length of 1586 feet and 36 to 56 feet in width from the Judge's Bungalow to Aundh Road No. 1 in November, 1925 on the original water-bound surface of trap stone metal. The cost per 100 square feet then was Rs. 15-4-0. This was renewed in December, 1936 with a 2½ INCHES PREMIX ASPHALT CARPET WITH A ¼-INCH SEAL COAT.

COST.—The cost per 100 square feet of the present surface is Rs. 14-8-0.

PRESENT CONDITION.—is fairly good.

M. 109 F. 6½ KIRKEE (OPPOSITE RACE COURSE)

CONPHALT SURFACE WITH A CENTRAL 18 FEET WIDTH OF 2½-INCHES PREMIXED ASPHALT WITH A ½-INCH SEAL COAT AND SIDES EACH 7 FEET WIDE OF CEMENT CONCRETE SLABS 7-INCHES—5- INCHES SECTION. This was laid on the original water-bound macadam surface reconditioned with a 2 inches layer of trap stone metal to bring it to the required camber. The cement concrete side-strips were laid towards the beginning of 1937 and the central asphalt carpet by May, 1937. The cost for the 7 inches-5 inches cement concrete slab is Rs. 28/- and that for the asphalt carpet Rs. 14/- per 100 square feet.

The longitudinal joints of the concrete and asphalt surfaces had to be subsequently repaired at places and the concrete slab had to be repaired where it cracked owing to softer foundations.

PRESENT CONDITION.—Good. The mean intensity of traffic in 24 hours for a 30-feet width was 9742 tons as per census taken on two consecutive days in January 1937.

MILE 107.

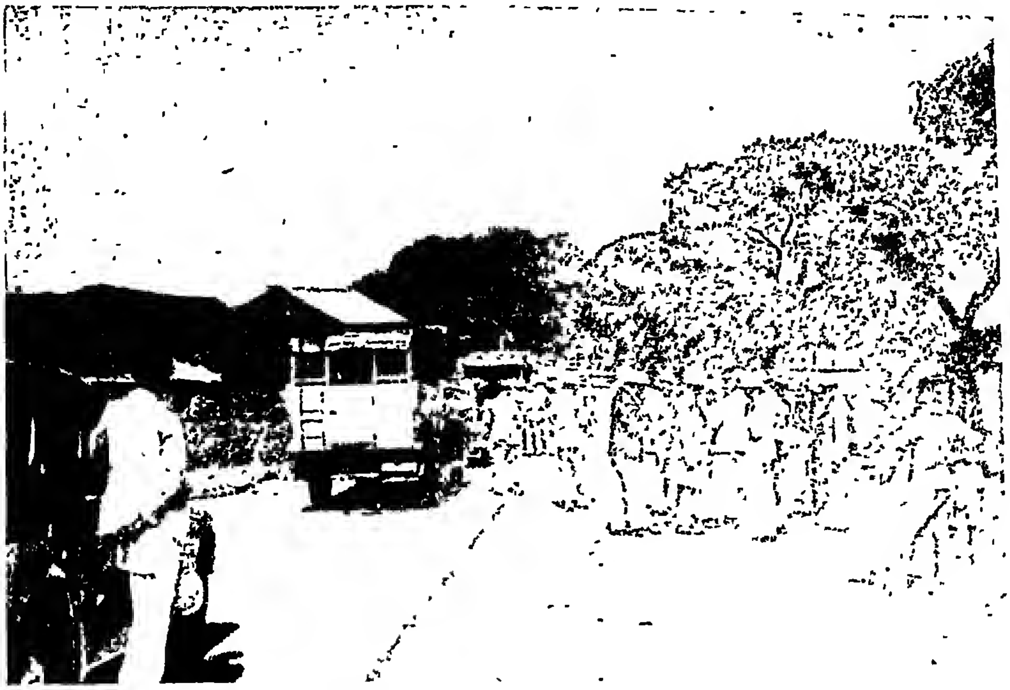
CEMENT CONCRETE 5-INCHES THICK (1:2:4) FOR 20 FEET WIDTH AND WATER-BOUND SURFACES FOR 2 FEET SIDE WIDTHS. This was laid in 1938 on the existing water-bound macadam surface of trap metal after reconditioning it with a 2 inches layer of new metal, so as to bring it to the required camber of 1 in 60. The concrete was mixed in a batch mixer and laid with insulating paper placed in between the slab and the sub-grade. Premoulded asphalt expansion joints were used every 35 feet apart. The consolidation of the concrete was done by hand-tamping and the resulting slab was cured for 21 days by ponding before traffic was allowed to pass over it.

The work was carried out departmentally except for the supply of materials and the rate for a 5 inches thick slab worked out to Rs. 26-11 per 100 square feet.

PRESENT CONDITION.—Good. The intensity of traffic in 24 hours for 20 feet width of road is 1221 tons as per census taken in December, 1938, see page 60.

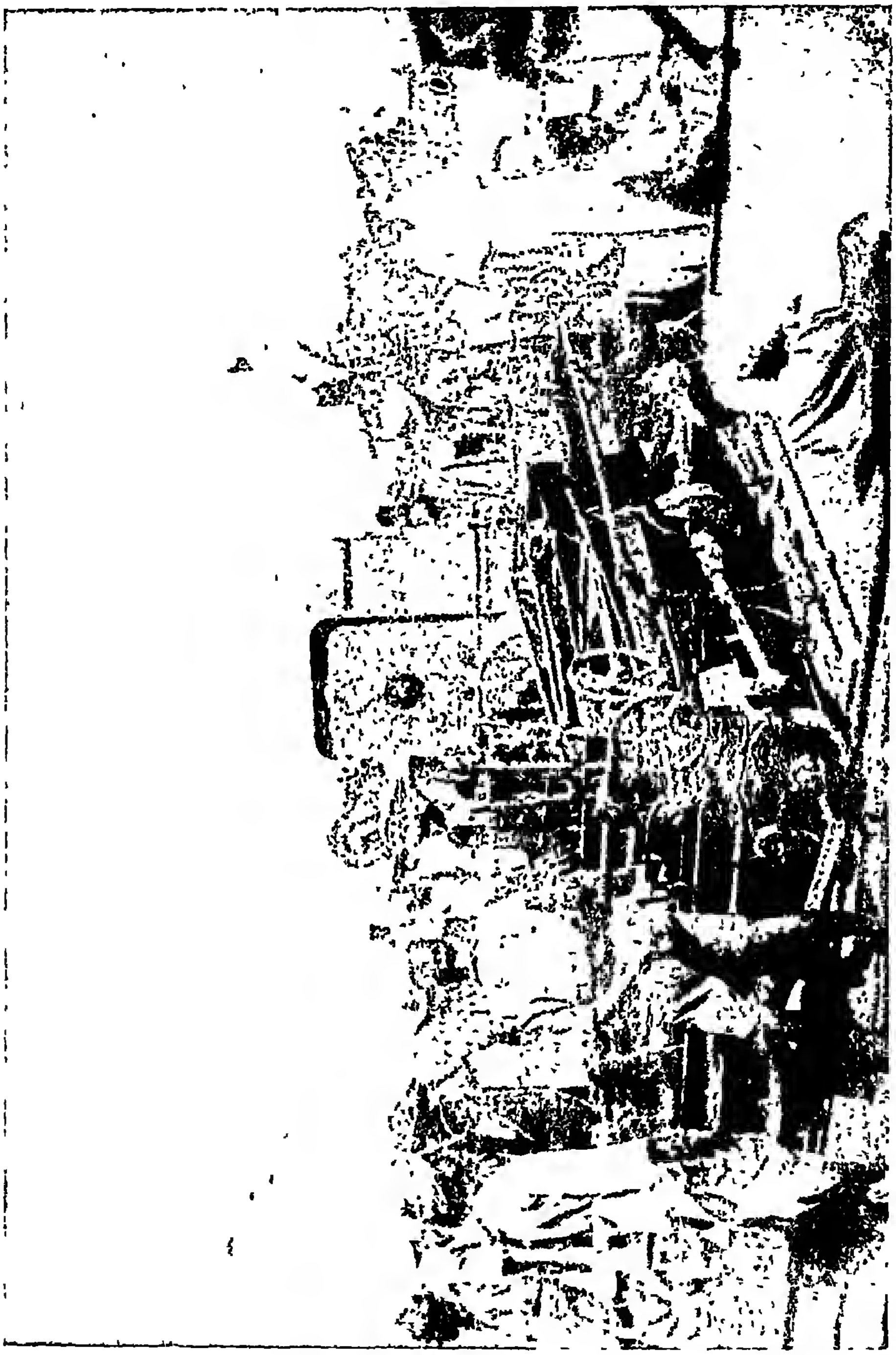
M. 103 F. 7 (WHERE ROAD-MAKING MACHINE WAS WORKING.)

CEMENT CONCRETE 5-INCHES THICK (1:2:4) FOR 20 FEET WIDTH. The intensity of traffic on this road and the details of this work are the same as for Mile 107 above with the exception that instead of handtamping, the consolidation is done by vibration produced by a Concrete Road-making machine supplied by the Associated Cement Companies, Limited.



BOMBAY-POONA ROAD. Hand-Tamped 5 inches Cement Concrete.

BOMBAY-POONA ROAD. 'Conphalt' construction.



BOMBAY-POONA ROAD

Concrete Road-Making Machine at work.

The machine consists of three main parts:—

1. A transversely oscillating screed which levels off the concrete dumped on the sub-grade roughly.

2. A vibrating bar, which compacts the concrete by vibration, to the finished level.

3. A finishing screed which smooths off the laitance layer and removes any excess laitance.

OPERATIONS OF THE MACHINE.—The Machine is worked as follows.—

The screed is set to about ½ inch above the finished level, and the vibrating bar is set to the finished level, and the screed is lifted clear. The machine then goes forward over the concrete dumped roughly on the sub-grade with the screed and the vibrating bar working.

When it has come to the end of the concrete, the screed is lifted clear, and the machine reverses over the concrete with the vibrating bar alone working.

At the end of this second run, the machine goes forward over the concrete again with the vibrating bar and the finishing screed in operation.

If these operations have been done correctly, the slab is finished with the exception of radiusing the edges of the slab by the finishing tool, which is done by hand.

FORMING EXPANSION JOINTS.—Great difficulty has been experienced in forming these correctly. The method suggested with which experiments are still going on is to put down a steel bulkhead, ½ inch thick, and slightly tapered, *i.e.*, thicker at the top than the bottom, where the expansion joints are to come.

This bulkhead has slots at the bottom so that the dowel bars at the joints can be fixed. The bulkhead is ½ inch less in height than the thickness of the slab and the machine is worked straight over the top of bulkhead. When the concrete is finished, then the thin concrete over the bulkhead is removed by hand, the bulkhead is withdrawn, and the ends of the slab pounded off in the usual way, by hand.

When the concrete is set, the joint is filled with bituminous material

CONCRETE MIXTURE.—Great difficulty was experienced at first in getting satisfactory results with this machine. This was finally traced in an incorrectly graded mixture. The mixture first used was quite satisfactory with hand-tamping, but slabs consolidated by the machine cracked on setting.

Finally, after some experiment, it was discovered that the mixture in use was too harsh, and not workable enough.

It was discovered that the mixture, to give good results, should contain no stone larger than 1¼ inches and that the sand used in the mixture should be as fine as can possibly be obtained locally.

The sand that was being stacked by Messrs. Pallonjee Eduljee and Sons in miles 104-105 had been approved by the Concrete Association as being satisfactory. The sand must be screened through a ¼-inch mesh screen.

The proportion of the mix had been altered from the normal 1 : 2 : 4 to 1 : 2.3 : 3.9, thus giving a large proportion of sand. Slabs made with this mix have proved satisfactory, and have shown no signs of cracking on setting. The proportion of water in each mix should be kept as low as possible. It is difficult to give any reliable indication as to the exact amount in each batch, as when the machine was being operated, the sand and coarse aggregate were both wet due to the monsoon.

With dry aggregate, probably about 4 to 4½ gallons per batch will be about correct, but this will have to be varied according to circumstances and experience. The Concrete Association recommend the driest mixture that the machine will work.

PLANT.—The concrete mixing plant consists of 4 Millars 10/7 concrete mixers. These will each mix approximately 850 cubic feet of concrete in an 8 hours' day. The time taken for each mix should not be more than 3 minutes, (2 minutes for mixing and 1 minute for loading, discharging, and putting in water, etc.).

To do this, it is essential to see that the loading hopper of the mixer is loaded and ready for the next mix, as soon as the hopper has been discharged into the mixing drum, so that no time is lost in waiting, with the mixer running idle.

With these 4 mixers, it should be easily possible to lay 1 furlong of 10 feet wide slab per day.

The machine itself can easily do a 35 feet long slab in half an hour, and for economical working, the mixers should keep up to this rate of progress as far as possible.

GENERAL.—One important difficulty in connection with this work is that of traffic. This machine can operate so rapidly that the question of traffic control due to long lenghts of half the road being closed due to the work going on, and especially due to finished lengths being cured is so great, that it has been decided to use diversion roads as far as possible.

Further, it has been decided to use rapid hardening cement, which can be opened to traffic in 10 days, as against 21 days with normal cement. It will be no more expensive to use rapid hardening cement, as less cement can be used, in the proportion of 1.2 to 1.4 as compared with ordinary cement.

The rapid hardening cement must be used for the whole road, as the Associated Cement Companies, Limited, had informed the authorities that due to technical reason concerned with manufacture, they can only supply very small quantities, or large quantities only on a regular order.

The delegates returned to Poona railway station at 1-30 p.m. for lunch and started again at 2-30 p.m. to visit the following roads.

NANA-SHANKARSHET ROAD.

MILE 3 F. O. JUNCTION OF NANA-SHANKARSHET ROAD AND POONA-BANGALORE ROAD NEAR SOWAR GATE.

2½-INCHES PREMIXED ASPHALT MACADAM WITH ½ INCH SEAL COAT FOR 20 FEET WIDTH.

The original water-bound macadam surface was reconditioned to the required camber of 1 in 40 with a 2 inches layer of new trap stone metal and then the Premix was laid over it in January, 1937. The cost of the work was Rs. 13/- per 100 square feet.

PRESENT CONDITION.—Good but the surface will need a liquid seal coat shortly.

POONA-BANGALORE ROAD.

MILE 3 F. 2 ONWARDS.

2½ INCHES PREMIXED ASPHALT MACADAM LAID IN TWO LAYERS, BOTTOM COURSE OF TRAP METAL 2 INCHES DOWN TO 1 INCH PRECOATED WITH SOCONY ASPHALT, GRADE 101-E HAVING 30/40 PENETRATION AND SOCOSOLE, A LIQUID SOLVENT, ADDED TO THE HOT ASPHALT AT 1 OUNCE TO 1 POUND OF ASPHALT. TOP COURSE OF PRECOATED STONE CHIPPINGS ⅝ INCH TO ⅛ INCH TO SERVE AS A SEAL COAT.

This was laid in 1937-38 on the original water-bound macadam road, reconditioned with a 2-inches layer of new trap metal and finished to a camber of 1 in 40. The premixed carpet was laid on it at a rate of Rs. 13-4-0 per 100 square feet. When exposed to the heavy traffic on the road it was noticed that it could not withstand the bullock cart traffic and hence after carrying out this type of modernisation upto Mile 6, it was decided to use the "Conphalt" type for the further portions, as the concrete side-widths to which the bullock cart traffic is automatically diverted stand the same very well and the central asphalted strip is available for fast traffic.

PRESENT CONDITION. The asphalted surface is badly rutted towards the sides especially on the side which brings loaded carts into the town.

Mean cart traffic intensity as per census taken for 8 consecutive days in June 1938 is 1257 tons in 24 hours on a width of 20 feet of the road, see page 61.

MILE 6 OF POONA-BANGALORE ROAD
(AT JUNCTION OF ASPHALTED AND 'CONPHALT' SURFACE).

CEMENT CONCRETE 5 INCHES THICK (1 : 2 : 4) FOR TWO SIDES 7½ FEET WIDE AND 2½ INCHES PREMIXED ASPHALT MACADAM WITH A SEAL COAT FOR CENTRAL 9 FEET WIDTH. This was laid in 1938-39 after reconditioning the original water-bound trap stone metalled surface with a new 2 inches layer and finishing to a camber of 1 in 40.

The central asphalted strip was laid in two layers, the bottom course consisting of precoated stone metal 2 inches down and the top course of good hard stone chippings 5/8 inches down to 1/8 inches precoated with asphalt.

The 7"—5" cement concrete slab on sides was carried out at Rs. 22/- per 100 square feet—a cut-throat competitive rate—and the central asphalted strip at Rs. 13/6/- per 100 square feet.

PRESENT CONDITION.—Good. Traffic intensity same as for Mile 3 F. 2 mentioned above.

PRINCE OF WALES DRIVE (OPPOSITE EMPRESS GARDENS).

'CONPHALT' WITH 7 INCHES—5 INCHES CEMENT CONCRETE SLABS (1:2:3.85) ON TWO SIDES AND CENTRAL STRIP OF 2-INCHES THICK ASPHALTIC CONCRETE. This was laid in March, 1939 to a width of 28 feet in all on the original water-bound macadam surface after properly reconditioning it with a 2-inches new metal layer. The concreted sides are each 7 feet 6 inches wide and the central strip of asphaltic concrete is 13 feet wide.

The cost of the concrete slab was Rs. 30/- and that of the asphalt concrete Rs. 13/- per 100 square feet.

PRESENT CONDITION.—Good

RICHARDSON ROAD.

'CONPHALT' OF CEMENT CONCRETE (1:2:3 85) SIDES 7 FEET 6 INCHES WIDE AND CENTRAL STRIP 15 FEET WIDE OF ASPHALTIC CONCRETE. Details with costs same as for the conphalt road for Prince of Wales Drive and carried out in March 1938.

PRESENT CONDITION.—Good.

The delegates returned to Poona Railway Station at 4 p.m., and went out sight seeing for an hour and a half in Poona City. They reassembled and left by special train at 6 p.m. reaching Bombay at 9.55 p.m.

Accompaniment to Government Circular Memorandum Public Works Department, No. 5495/27, dated the 13th June 1939.

ROAD TRAFFIC CENSUS FORM.

Census of traffic at M. 103 F. 6 on Bombay-Poona Road in the Poona Division in the 24 hours ending at 6 a.m. on 27-12-1938.

Enumerator's name, Mr. P. G. Joshi, *Karkun.*

Kind of traffic	Number passing (each to be indicated by a stroke from right to left thus /,/,/,/) Left.	Right.	Total number passing	Average weight or equivalent weight (laden or empty)	Total weight or equivalent weight
				Tons.	Tons.
1. Motor lorries or buses, (all types of power driven vehicles):—					
(*a*) With pneumatic tyres.	126	112	238	3 00	714
(*b*) With solid rubber or steel tyres.	—	—	—	6 00	—
(*c*) Armoured cars and tanks.	—	—	—	—	—
2. Motor cars. Steam and Oil Rollers.	55	57	112	1 50	168
3. Motor cycles.	5	5	10	0 20	2
4. Animal drawn vehicles :—					
(*a*) Bullock carts.	144	159	303	1.00	303
(*b*) Passenger vehicles, Cycles.	—	—	—	—	—
(*c*) Cycles.	169	171	340	0 10	34
					1221

Note—Weights given are for Mofussil conditions and may require modification where heavy vehicles are in frequent use *e g.*, in large towns.

This census applies approximately to the length of the same road from Vadgaon Chakan Junction in Miles 91/2 to Dapuri Junction in Mile 107/4.

Total weight passing during 24 hours = 1221 tons .. .. (i)

Surfaced width of roadway = 18 feet or 6 yards .. .. (ii)

Tons passing per 24 hours per yard of surfaced width (i) ÷ (ii) $\frac{1221}{6} = 203.5$

(Sd.) P. G. Joshi, *Karkun.*

Accompaniment to Government Circular Memorandum Public Works Department, No. 5495/27, dated the 13th June 1939.

ROAD TRAFFIC CENSUS FORM.

Census of traffic at M. 3 F. O on Poona-Bangalore Road in the Poona Division (Sowar Gate to Bhatghar Junction) in the week ending at 8 a.m., on 8th June, 1938. Enumerator's name. Mr. V. M. Brahme, *Road Karkun.*

Kind of traffic	Number passing (each to be indicated by a stroke from right to left thus /,/,/,/)	Total number passing	Average weight or equivalent weight (laden or empty)	Total weight or equivalent weight
			Tons.	Tons.
1. Motor lorries or buses, (all types of power driven vehicles):—				
(a) With pneumatic tyres.		2021	3.00	6063
(b) With solid rubber or steel tyres.		—	6.00	—
(c) Armoured cars and tanks.		—	—	—
2. Motor cars. Steam and Oil Rollers.		912	1.50	1413
3. Motor cycles.		9	0.20	say 2
4. Animal drawn vehicles:—				
(a) Bullock carts		1239	1.00	1239
(b) Passenger vehicles.		106	0 75	79
				8796

Note.—Weights given are for mofussil conditions and may require modification where heavy vehicles are in frequent use, e.g., in large towns.

This census applies approximately to the length of the same road from Sowar Gate in M. 3/0 to Bhatghar Junction in M. 25/4.

Total weight passing during 24 hours=8796/7=1256 tons .. (i)
Surfaced width of roadway=20 feet=7 yards (say) (ii)
Tons passing per 24 hours per yard of surfaced width (i) ÷ (ii)

1256 x 1/7 = 179 5 tons, say 180 tons

(Signature of enumerator.)

Accompaniment to Government Circular Memorandum Public Works Department, No. 5495/27, dated the 13th June 1939.

ROAD TRAFFIC CENSUS FORM.

STATION OF CENSUS—Elphinstone Road Junction.

From Murray Bridge to Nasik Road Junction.

Census of traffic at M. 110 on Bombay-Poona Road in the Poona Division in the 24 hours ending at 6 a.m. on 5-1-1937.

Enumerator's names:—1. Shankar Babaji, 2. Balchandra Vishnu, 3. Rajaram Bhikaji, 4. Prabhakar Narayan, 5. Dattatraya Ramchandra and 6. Sonba Ekanath.

Kind of traffic	Number passing (each to be indicated by a stroke from right to left thus /,/,/,/) Left.	Right.	Total number passing	Average weight or equivalent weight (laden or empty)	Total weight or equivalent weight
				Tons.	Tons.
1. Motor lorries or buses, (all types of power driven vehicles):—					
(*a*) With pneumatic tyres.	1352	1200	2552	3.00	7656.0
(*b*) With solid rubber or steel tyres.	—	—	—	—	—
(*c*) Armoured cars and tanks.	—	—	—	6.00	
2 Motor cars. Steam and Oil Rollers.	480	429	909	1.50	1363.5
3. Motor cycles.	68	42	110	0.20	22.0
4. Animal drawn vehicles:—					
(*a*). Bullock carts.	979	926	1905	1.00	1905.0
(*b*) Passenger vehicles.	—	—	—	—	—
(*c*) Tongas.	222	153	375	0.50	187.5
					11134

Note :—Weights given are for mofussil conditions and may require modification where heavy vehicles are in frequent use, *e.g.*, in large towns.

This census applies approximately to the length of the same road 11880 feet near M. 110.

Total weight passing during 24 hours = 11134 tons .. .. (i)

Surfaced width of roadway feet = 30 feet or 10 yards .. .. (ii)

Tons passing per 24 hours per yard of surfaced width (i) ÷ (ii)

= 11134 ÷ 10 = 1113.4 tons.

(Signature of enumerators.)

Accompaniment to Government Circular Memorandum Public Works Department, No. 5495/27, dated the 13th June 1939.

ROAD TRAFFIC CENSUS FORM.

STATION OF CENSUS :—Elphinstone Road Junction.

From Murray Bridge to Nasik Road Junction.

Census of traffic at M. 110 on Bombay-Poona Road in the Poona Division in the 24 hours ending at on 6th January, 1937.

Enumerator's names:—1. Shankar Babaji, 2. Balchandra Vishnu, 3. Rajaram Bhikaji, 4. Prabhakar Narayan, 5. Dattatraya Ramchandra and 6. Sonaba Ekanath.

Kind of traffic	Number passing (each to be indicated by a stroke from right to left thus /,/,/,/) Left.	Right.	Total number passing	Average weight or equivalent weight (laden or empty)	Total weight or equivalent weight
				Tons.	Tons.
1. Motor lorries or buses, (all types of power driven vehicles:—					
(*a*) With pneumatic tyres.	531	665	1196	3.00	3588
(*b*) With solid rubber or steel tyres.	—	—	—	6 00	—
(*c*) Armoured cars and tanks.	—	—	—	—	—
2. Motor cars Steam and oil Rollers.	298	250	548	1.50	822.00
3. Motor cycles.	55	33	88	0.20	17.60
4. Animal drawn vehicles):—					
(*a*). Bullock carts.	2379	1484	3863	1.00	3863.00
(*b*) Passenger vehicles.	—	—	—	—	—
(*c*) Tongas	73	45	118	0.50	59.00
					8349.60 say

Note:—Weights given are for mofussil conditions and may require modification where heavy vehicles are in frequent use, e.g. in large towns.

This census applies approximately to the length of the same road 11880 feet near M. 110.

Total weight passing during 24 hours = 8350 tons .. .. (i)
Surfaced width of roadway feet = 30 feet or 10 yards. .. .. (ii)
Tons passing per 24 hours per yard of surfaced width (i) ÷ (ii) = 835.0
Therefore, average of results on pages 62 and 63 for the same portion of the road = (1113·4 + 835) ÷ 2 = 1948·4 ÷ 2 = 974·2 Tons.

(Signature of enumerators.)

** Saturday, December 9, 1939.*

The delegates assembled at the Bus stand at traffic island near Church Gate Railway Station and proceeded to inspect the Bombay-Agra Road.

(A) MILES 9/1 TO 10/0.

3-INCH FULL-GROUT ASPHALT MACADAM SURFACE.

(A typical cross section is on page 99)

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

3-inch asphalt macadam full-grout surface was done in 1928-29 with Burmah-Shell products, *viz.*, Mexphalt and Spramex. The details of treatment are given in the accompanying brief Specification No. 1, pages 78 to 79

(3) *Cost of treatment per 100 square feet :—*

Rs. 39/10/-.

(4) *Subsequent treatments : —*

3-inch full-grout asphalt macadam surface, done in 1929, stood heavy traffic fairly well till 1935 when two liquid seal coats were given to prevent the base coat at a cost of Rs. 9/-per 100 square feet.

(5) *Present condition :—*

Since the treatment of two liquid seal coats the surface has stood quite all right and is expected to last few years more without heavy repairs.

(6) *Further remarks :—*

This was the first asphalt work done in this Division and being in low lying portion often gets submerged under abnormal floods. But presumably due to solid sub-grade and proper surface drainage the surface has stood very well.

(B) MILES 10/0 TO 13/1.

2-INCH FULL-GROUT ASPHALT MACADAM SURFACE.

(A typical cross section is on page 100).

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

2-inch full-grout asphalt macadam surface was done over the reconditioned water-bound macadam surface in 1932-33 with Burmah-Shell products *viz.*, Mexphalt and Spramex as per details given in Specification No. 2, pages 79 and 80.

* An index plan of works visited on 9.12.39 is at page 109.

(3) *Cost of treatment per 100 square feet :—*

Rs. 24/14/-.

(4) *Subsequent treatment :—*

2-inch full-grout asphalt macadam done in 1932-33 stood tolerably well till 1935 requiring very little repairs here and there.

In 1935, portion from 10/0 to 10/3 was given a two liquid seal coat at a cost of Rs. 9/- per 100 square feet. Portion 10/3 to 11/2 was given 1¼-inch full-grout asphalt macadam over the worn out 2-inch asphalt macadam done originally. Portion 11/2 to 13/1 has also worn out considerably and requires immediate attention.

(5) *Present condition :—*

According to the subsequent surface treatment given to this portion, whole length may be divided into three parts *viz :—*

10/0 to 10/3—Quite satisfactory after giving two liquid seal coats.

10/3 to 11/2—Very well after giving 1¼-inch full-grout treatment.

11/2 to 13/1—Many pot-holes have been formed. Due to piercing rains, seal coat has been cut up and washed away in many places and requires immediate attention.

*Note :—*Arrangements have been made to fill up all pot-holes and give a thin liquid seal over the whole road width.

(6) *Further remarks :—*

In giving two liquid seal coats in portion 10/0 to 10/3 over the worn out 2-inch asphalt macadam it was seen that smaller metal used for seal coat used to get crushed under heavy motor traffic thereby reducing the life of seal coat. It was, therefore, later on decided to adopt 1¼-inch full-grout method for repairing the surface as 1-inch metal required for this treatment was strong enough to bear heavy traffic.

(C) MILES 13/1 TO 14/6.

2½-INCH FULL-GROUT ASPHALT MACADAM SURFACE

(A typical cross section is on page 101).

(1) *Nature of original surface :—*

13/1 to 13/6—Water-bound macadam surface treated with ½-inch premixed seal coat which had worn out.

13/6 to 14/6—Water-bound macadam surface.

(2) *Surface treatment given :—*

2½-inch full-grout asphalt macadam surface was done over the existing road surface without reconditioning it as per Specification No. 3, page 80. The work of filling pot-holes, inequalities and correcting cross-fall and grade was done by penetration method in the first instance and

$2\frac{1}{2}$-inch full grout asphalt macadam was laid over it. In modernizing this portion, both Socony and Burmah-Shell products were used.

(3) *Cost of treatment per 100 square feet :—*

Rs. 23/10/-.

(4) *Subsequent treatment :—*

Since modernizing the roadway with $2\frac{1}{2}$-inch asphalt macadam surface in 1937, no repairs have been carried out in this length.

(5) *Present condition :—*

Good in all furlongs.

(6) *Further remarks :—*

In order to take full advantage of the then existing hard water-bound macadam, it was proposed to fill in all pot-holes and irregularities and correct cross-fall and grade by penetration method. This arrangement greatly helped in pushing the progress of work which would otherwise have been hampered by slow progress of reconditioning the sub-grade with water-bound macadam. Moreover, the cost of the method now adopted has worked out practically the same as that required for reconditioning with water-bound macadam.

(D) MILES 14/6 TO 15/0.

$2\frac{1}{2}$-INCH CORROID ROAD SURFACE

(A typical cross section is on page 102).

(1) *Nature of original surface.*

Water-bound macadam.

(2) *Surface treatment given :—*

$2\frac{1}{2}$-inch Corroid Road Surface was done in 1938 by premixed method as per Specification No. 4, pages 81 to 82. This product was used for the first time in the Division and the road surface treated with it has stood well.

(3) *Cost of treatment per 100 square feet :—*

Rs. 23/10/-.

(4) *Subsequent treatment :—*

No repairs have been carried out since 1938.

(5) *Present condition :—*

Good.

(6) *Further remarks :—*

Corroid Products present a non-skidding surface. As a first experiment it has stood well.

(E) MILES 15/0 TO 17/8.

$2\frac{1}{2}$-INCH PREMIXED ASPHALT MACADAM SURFACE WITHOUT RECONDITIONING SUB-GRADE.

(A typical cross section is on page 103).

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

$2\frac{1}{2}$-inch Premixed asphalt macadam surface was done over existing water-bound road surface without reconditioning it as per Specification No. 5, pages 82 to 83. In order to take full advantage of the working season so as to do maximum possible length before monsoon of 1937 and also to secure solid hard sub-grade, it was decided to fill in pot-holes and correct cross-fall and grade with asphalted metal and then to lay over it $2\frac{1}{2}$-inch premixed asphalt macadam surface.

(3) *Cost of treatment per 100 square feet :—*

Rs. 23/10/-.

(4) *Subsequent treatments :—*

No repairs have been carried out since 1937.

(5) *Present condition :—*

Good.

(6) *Further remarks :—*

From the experience gained in this district it was seen that it is rather difficult to secure hard sub-grade for asphalting after reconditioning during hot months and hence the method of filling pot-holes, correcting camber and grade with asphalted metal was adopted and this has proved a good success.

Moreover, with a view to secure good out-turn, it was decided to divide this work into the following three main parts :—

(1) Purchasing of all kinds of metal required (to be done Departmentally.)

(2) Purchasing of asphalt (to be done Departmentally).

(3) Labour charges for correcting sub-grade with asphalted metal and laying $2\frac{1}{2}$-inch premixed asphalt macadam surface, (to be let out on regular contract).

This arrangement insured proper check at all stages, and the present condition of the road, it is believed, fully justifies it.

(F) MILES 17/8 TO 23/2.

$2\frac{1}{2}$-INCH PREMIXED ASPHALT MACDAM SURFACE ON A RECONDITIONED SUB-GRADE

(A typical cross section is on page 104).

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

$2\frac{1}{2}$-inch premixed asphalt macadam surface was done after reconditioning the sub-grade with water-bound macadam as per Specification No. 6, pages 83 to 84.

The work was carried out as under :—

Miles 17/8 to 22/2	..	.. 1935-36.
Miles 22/2 to 23/2	..	.. 1933-34.

(3) *Cost of treatment per 100 square feet :—*

For portion from 17/8 to 22/2	..	.. Rs. 19/7/-.
For portion from 22/2 to 23/2	..	.. Rs. 30/3/6.

(4) *Subsequent treatments :—*

Portion 17/8 to 22/2 after its completion in 1937 has not been treated up till now, except for a few patches here and there.

Portion from 22/2 to 22/6 showed fine cracks in seal coat and hence a fresh light seal coat was given over it in 1939 at a cost of Rs. 5/-/- per 100 square feet.

Portion from 22/6 to 23/2 showed more wear and tear of the seal coat and had many pot-holes, and many undulations were formed in it. It was, therefore, treated with two liquid seal coats in 1938 at a cost of Rs. 9/-/- per 100 square feet.

(5) *Present condition :—*

First furlong of mile 18 requires immediate attention. Rest of the portion is in good condition.

(6) *Further remarks :—*

The present condition of this length varies according to the location of the road portion, *viz.*, the surface has stood very well in high and dry portion and road passing through low lying portion shows signs of undulations and tendency of forming pot-holes on the sides.

In order to protect sides, stone-kerbing has been used in this length.

(G) MILES 23/2 TO 23/8.

1½-INCH FULL-GROUT ASPHALT MACADAM SURFACE.

(A typical cross-section is on page 105.)

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

1½-inch full-grout asphalt macadam surface was done after filling all pot-holes and correcting camber and cross-fall, by penetration method as per Specification No. 7, pages 84 to 85 in 1938.

(3) *Cost of treatment per 100 square feet :—*

Rs. 15/-.

(4) *Subsequent treatments :—*

Since 1938 no repairs have been required for this portion

(5) *Present condition :—*

Very good.

(6) *Further remarks :—*

The method of 2½-inch full-grout has been adopted in place of surface painting with two liquid seal coats. It was noticed that owing to abnormally heavy and piercing rain-fall of about 120 inches of this District, and due to heavy bus traffic, two liquid seal coats (costing about Rs. 9/-/- per 100 square feet) given on the main roads used to get cut up within a year or so and road used to be damaged beyond repairs. The present method was, therefore, proposed to meet all requirements and the present condition justifies the same.

(H) MILES 23/8 TO 26/1.

2½-INCH FULL-GROUT ASPHALT SURFACE WITHOUT RE-CONDITIONING SUB-GRADE.

(A typical cross-section is on page 101.)

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

2½-inch full-grout asphalt macadam surface was done over the existing road surface without reconditioning it as per Specification No. 3, page 80 in 1939.

(3) *Cost of treatment per 100 square feet :—*

Rs. 21/8/-.

(4) *Subsequent treatment :—*

No repairs have been carried out since March 1939.

(5) *Present condition :—*

Good.

(6) *Further remarks :—*

The work of filling pot-holes and correcting camber and grade was done by penetration method in the first instance and then 2½-inch asphalt macadam was laid over it. This method greatly helped to push on the progress of the work.

KASHELI BRIDGE :—MILES 26/1 TO 26/3.

(I) MILES 26/3 TO 26/7.

2-INCH SEMI-GROUT ASPHALT MACADAM SURFACE.

(A typical cross-section is on page 106).

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

2-inch semi-grout asphalt macadam surface was done as per Specification No. 8, pages 85 to 86 in 1937.

(3) *Cost of treatment per 100 square feet :—*

Rs. 14/-/-.

(4) *Subsequent treatment :—*

No repairs have been carried out to this length since 1937.

(5) *Present condition :—*

Good.

(6) *Further remarks :—*

Portion of this road 26/3 to 26/7 runs across the Ulhas Creek and due to heavy winds, all blindage used to get blown away leaving nobbly metalled surface exposed for the traffic. Two liquid seal coats as a surface painting would not have stood the piercing heavy rain-fall of this District and heavy motor traffic running over this length. It was, therefore, proposed to adopt 2-inch semi-grout method and the same has stood very well.

BOMBAY-POONA ROAD

KALWA BRIDGE:—Mile 23/3 (Details on page 76.)

(J) MILES 23/4 TO 23/5.

1½-INCH PREMIXED SHALIMAR TAR CARPET.

(A typical cross-section is on page 107).

(1) *Nature of original surface :—*

Water-bound macadam.

(2) *Surface treatment given :—*

1½-inch Premixed Shalimar Carpet was laid after reconditioning the existing water-bound surface as per Specification No. 9, pages 86 to 87 in 1937.

(3) *Cost of treatment per 100 square feet :—*

Rs. 13/-.

(4) *Subsequent treatments :—*

No repairs have been carried out to this portion since 1938.

(5) *Present condition :—*

Good.

(6) *Further remarks :—*

1½-inch Shalimar Tar carpet was laid as an experiment in 1937 and has stood very well under worst weather conditions and heavy motor traffic runing along the Bombay-Poona road.

Shalimar products present a non-skidding surface. From the experience gained, it is seen that owing to heavy rain-fall and

heavy traffic any treatment of Shali mar products thinner than 1½-inch does not suit for roads in this Division.

(K) MILES 24/0 TO 25/4.

5-INCH THICK CEMENT CONCRETE ROAD.

(A typical cross-section is on page 108).

(1) *Nature of original surface* :—

Water-bound macadam.

(2) *Surface treatment given* :—

Existing water-bound surface was reconditioned to correct cross-fall and grade with 3-inch water-bound macadam, and concrete slab of 5-inch thickness was laid over it as per Specification No. 10, pages 87 to 98 in 1939 (February to May).

(3) *Cost of treatment per 100 square feet* :—

Rs. 29/-.

(4) *Subsequent treatment* :—

Not required.

(5) *Present condition* :—

Good.

(6) *Further remarks* :—

Portion done before monsoon of 1939 was submerged under abnormal floods with 3 feet of water over the concrete road surface in Mile 25.

TRAFFIC CENSUS IN THE THANA DISTRICT.
FOR ONE DAY OF 24 HOURS.

Place and time of observation.	Bombay-Agra Road, Section I. 23-12-38.
Nature of road at the above place.	Asphalt Surface.
Full width of road.	27 Feet.
Metalled width of road.	24 Feet over-all (18 Feet Asphalt).

Kind of traffic.	Total number passing.	Total weight. (tons)	Width of road. (yards)	Intensity of traffic per 24 hours per yard in tons.
(1) Motor or steam lorries with solid or steel tyres (5 tons each)..	—	—	—	—
(2) Motor lorries and buses conveying more than 25 passengers with pneumatic tyres (4 tons each)	411	1644	—	—
(3) -do- less than 25 passengers (3 tons each)	436	1308	—	—
(4) Motor cars and Taxis ($1\frac{1}{2}$ tons each) ..	493	739	—	—
(5) Motor cycles (0.2 ton each)	12	2	—	—
(6) Bullock carts (loaded) weighing (1 ton each) ..	291	291	—	—
(7) Passenger vehicles ($\frac{3}{4}$ ton each) ..	11	9	—	—
(8) Animals each (.06 ton each) ..	260	—	—	—
Total	..	3993	6	666

TRAFFIC CENSUS IN THE THANA DISTRICT.

FOR ONE DAY OF 24 HOURS.

Place and time of observation.	Bombay-Agra Road, Section, II. 24-2-39
Nature of road at the above place.	Asphalt Surface.
Full width of road.	27 Feet.
Metalled width of road.	24 Feet over-all (18 Feet Asphalt).

Kind of traffic.	Total number passing.	Total weight. (tons)	Width of road. (yards)	Intensity of traffic per 24 hours per yard in tons.
(1) Motor or steam lorries with solid or steel tyres (5 tons each)	401	2005	—	—
(2) Motor lorries & buses conveying more than 25 passengers with pneumatic tyres (4 tons each) ..	—	—	—	—
(3) -do-less than 25 passengers (3 tons each)	—	—	—	—
(4) Motor cars and Taxis ($1\frac{1}{2}$ tons each) ..	65	97·50	—	—
(5) Motor cycles (0.2 ton each) ..	1	—	—	—
(6) Bullock carts (loaded) (1 ton each) ..	82	82	—	—
(7) Passenger vehicles ($\frac{3}{4}$ ton each) ..	9	6.75	—	—
(8) Animals (.06 ton each) ..	138	—	—	—
Total	..	2191	6	365

TRAFFIC CENSUS IN THE THANA DISTRICT.
FOR ONE DAY OF 24 HOURS.

Place and time of observation.	Bombay-Poona Road. 14-2-39.
Nature of road at the above place.	Asphalt Surface.
Full width of road.	24 Feet.
Metalled width of road.	21 Feet over-all, (18 Feet Asphalt.)

Kind of traffic.	Total Number passing.	Total weight. (tons)	Width of road. (yards)	Intensity of traffic per 24 hours per yard in tons.
(1) Motor or steam lorries with solid or steel tyres (5 tons each)..	—	—	—	—
(2) Motor lorries and buses conveying more than 25 passengers with pneumatic tyres (4 tons each)	205	820	—	—
(3) -do- less than 25 passengers (3 tons each)	287	861	—	—
(4) Motor cars and Taxis ($1\frac{1}{2}$ tons each) ..	280	420	—	—
(5) Motor cycles (0.2 ton each) ..	3	1	—	—
(6) Bullock carts (loaded) (1 ton each) ..	500	500	—	—
(7) Passenger vehicles ($\frac{3}{4}$ ton each)	437	328	—	—
(8) Animals (·06 ton each)	68	—	—	—
Total	..	2930	6	488

DESCRIPTION OF KALWA BRIDGE.

ON THE

BOMBAY-POONA ROAD.

MILE 24.

(1) Province or State ..	Bombay Presidency (Northern Circle.)
(2) Name and nature of bridge	Kalwa Bridge over Thana creek (Masonry bridge)
(3) Road and milage ..	Bombay-Poona Road, Mile 23/3.
(4) Year of construction ..	1919.
(5) Nature of stream, *e.g.* bed slope maximum velocity ..	Tidal creek.
(6) Width and type of road ..	25 feet width without foot-path, Class I Road.
(7) Length between faces of abutments ..	734 feet-9 inches.
(8) Number of Spans ..	15
(9) Length of each span ..	7 Spans, Bombay side, each of 40 feet. Central Span of 76 feet. 7 Spans Poona side, each of 40 feet.
(10) (a) Height of top of piers above bed level ..	Maximum 25.34 feet. Minimum 7 87 feet.
(b) Height of top of piers above foundation level ..	Maximum 29 25 feet. Minimum 17.62 feet.
(11) (a) Height above bed level up to finished decking..	Maximum 37.78 feet. Minimum 20.37 feet.
(b) Height above foundation level up to decking ..	Maximum 41.70 feet. Minimum 30.15 feet.
(12) Founded on (Geology) ..	Rock.
(13) Types, Section etc of foundations ..	Piers Nos. 1 to 5 :—Cement concrete foundation *in situ*. Piers Nos 10 to 14 :—Cement concrete foundations *in situ*. Piers Nos. 6, 7, 8, 9 :—Cement concrete block foundations having kerbs of heavy cencrete blocks and internal space filled in with cement concrete *in situ*.

(14)	Type, Section etc. of Piers	Stone and cement masonry up to low tide level. Stone and lime masonry above L W. level with face masonry set in cement and hearting in lime mortar up to H.F.L. Masonry above H.F.L. is of lime mortar.
(15)	Type, Section etc. of abutments	(Same as against 14 above).
(16)	Type, Section, etc., of arches or girders	For central span of 76 feet—Rib construction, Precast cement concrete blocks. For the remaining spans of 40 feet each —precast cement concrete blocks with stone arch facing on both up and down-stream side.
(17)	Type, Section, etc., of decking	R. C. C. decking for central span only.
(18)	Total cost of bridge ..	Estimated Rs. 3,00,222, Actual Rs. 2,98,000.
(19)	Cost per foot run of Roadway ..	Rs. 405-10-0.
(20)	Cost per square foot of Roadway .. (On carriageway only excluding foot-paths)	Rs. 16-4-0.
(21)	Cost per square foot of openings .. (Spring to Bed level)	Rs. 2-15-4.
(22)	Cost per square foot of elevation area, i.e., from the Roadway to the foundation ..	Rs. 5-7-0.
(23)	Annual cost of maintenance, average of recent actuals or budget (give separately cost of painting reduced to annual average per R. ft. of Roadway) ..	Not traceabl,e, but it will be Rs. 150/.
(24)	Percentage of maintenance to capital cost ..	½ per cent.
(25)	Premissible load ..	15 units B. S. U Loading.

SPECIFICATION No. 1.

THREE-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE.

(i) BRUSHING.

Prior to the spreading of metal for asphalt surface, the waterbound surface shall be swept very clean to remove all blinding material so as to expose the metal surface. Over this a light priming coat of heated Spramex at 60 degrees Fahrenheit, at the rate of 2¼-gallons per 100 square feet will be given. This will be spread with bass-brooms so as to have an even thin layer.

(ii) THREE-INCH ASPHALT MACADAM SURFACE.

After the surface is treated as above and after removing all loose and foreign matter, the coarse aggregate of the approved quality shall be spread upon the base uniformly in a loose layer of 4½ inches (about 36 cubic feet metal being used per 100 square feet). The size of metal shall be 2½-inch to 2-inch gauge. Every precaution shall be taken to prevent the aggregate from becoming mixed or coated with dust or other objectionable matter before and after spreading.

The coarse aggregate shall then be dry-rolled with a steam road-roller weighing not less than 10 tons. The rolling shall start longitudinally at the sides and proceed towards the centre of the pavement over-lapping on successive strips by at least one half of the width of the roller. The compacted coarse aggregate shall possess a fairly firm and even surface true to the grades and cross sections shown on the plans and present a texture which will allow a uniform penetration of the asphalt. If any irregularities appear during or after rolling, they shall be remedied by loosening the surface and removing or adding coarse aggregate as may be required after which the area disturbed including the surrounding surface shall be rolled until satisfactorily compacted to a uniform surface. All coarse aggregate which becomes coated or mixed with dirt, dust or foreign substances prior to the application of asphalt shall be removed and replaced by clean aggregate of the same kind and compacted as specified.

(iii) FIRST APPLICATION OF ASPHALT.

(*a*) Upon the rolled coarse aggregate asphalt of the required grade and quality shall be uniformly applied at the rate of 13 to 17 gallons per 100 square feet as directed by the Engineer.

(*b*) Asphalt shall be applied only when the coarse aggregate is thoroughly dry for its entire depth and is passed by the Engineer or his Assistant.

(*c*) Application of the asphalt shall be made by means of a pressure distributor or with hand pouring pots but preferably by the former.

(*d*) The asphalt shall be heated in kettles to secure uniform heating of the entire content and shall be brought to a temperature of 300 degrees to 350 degrees Fahrenheit as directed by the Engineer. A thermometer must be provided to determine the temperature of the asphalt during heating or prior to application.

(*e*) Hand pouring pots used for applying asphalt shall have a capacity of not less than 3 gallons and shall be equipped with slotted spouts so placed that when the can is emptied by carrying it forward with the end of the spout close to the road surface the width of application shall not be less than 8 inches Each pot shall be measured off and the pouring operation conducted so that the rate of application will be uniform as the pot is emptied. The direction of successive pourings shall be revised. Application shall be made at such an angle to the centre line of the road or longitudinally as directed by the Engineer. During the operation of pouring, the holes of the pot shall be kept within 6 inches of the surface of the road. In distributing, slots shall be kept free from obstructions and shall be cleaned as necessary to insure a uniform distributing aperture. A narrow spout pouring pot may be used to apply asphalt it is necessary to touch up all spots unavoidably missed during the original application.

(*iv*) FILLING SURFACE VOIDS WITH INTERMEDIATE AGGREGATE.

After the first application of asphalt and if practicable while still warm, a thin layer of dry intermediate aggregate consisting of ½-inch to ¾-inch metal shall be broad-casted over the treated surface in such quantity as to fill the surface voids and just cover the treatment. 4 to 6 cubic feet of metal per 100 square feet is required. It shall then be broomed, if necessary, to break up all heaps and produce a uniform covering; after which the pavement shall be steam-rolled until thoroughly compacted and interlocked.

Suitable precautions shall be taken to prevent the distribution of intermediate aggregate over portion of the coarse aggregate which has not received the application of asphalt and in no case shall be dumped directly upon either the treated or untreated coarse aggregate.

(*v*) SEAL COAT.

After intermediate aggregate has been thoroughly rolled stiff, the pavement shall be swept clean of all loose material and treated with a second application of heated asphalt under the same condition and in the same manner as previously specified except that the rate of application shall be from 5½ to 8¼ gallons per 100 square feet.

If hand-pouring pots are used, the lines of distribution shall cross those of the first application at an angle of approximately 90 degrees. After the second application of asphalt and if practicable, while it is still warm, dry fine aggregate consisting of ¼-inch grit shall be broad-casted over the surface and rolled until thoroughly bonded to the road (quantity of grit per 100 square feet being 4 cubic feet). As required, additional fine aggregate shall be spread and broomed over the surface during rolling in sufficient quantity to take up all excess of asphalt.

Upon completion of the pavement, however, only a very light uniform covering of loose aggregate shall be allowed to remain on the road. The finished surface shall be uniform, free from ruts or irregularities in camber and true to the required grade.

(*vi*) PROTECTION OF BASE-COAT.

During the period between the initial compaction of the coarse aggregate and completion of the seal coat, the surface shall be protected from all traffic other than that absolutely essential.

SPECIFICATION No. 2.

TWO-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE.

(*i*) BRUSHING.

Same as in Specification No. 1.

(*ii*) TWO-INCH ASPHALT MACADAM SURFACE.

After the surface is treated as above and after removing all loose and foreign matter, the coarse aggregate of the approved quality shall be spread upon the base uniformly in a loose layer of 2¾ inches (about 24 cubic feet of metal being used per 100 square feet). The size of metal shall be 1½-inch to 2-inch gauge. Every precaution shall be taken to prevent the aggregate from becoming mixed or coated with dust or other objectionable matter before and after spreading.

(*iii*) FIRST APPLICATION OF ASPHALT.

(*a*) Upon the rolled coarse aggregate, asphalt of the required grade and quality shall be uniformly applied at the rate of 9 to 12 gallons per 100 square feet as directed by the Engineer.

Paras (b), (c), (d), and (e). Same as in Specification No. 1.

(*iv*) FILLING SURFACE VOIDS WITH INTERMEDIATE AGGREGATE.

Same as in Specification No. 1.

(*v*) SEAL COAT.

Same as in Specification No. 1.

(*vi*) PROTECTION OF BASE-COAT.

Same as in Specification No. 1.

SPECIFICATION No. 3.

TWO AND A HALF-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE.

(Without reconditioning Sub-grade)

The existing water-bound macadam surface and especially the pot-holes and uneven surface shall be thoroughly cleaned of all dust so as to expose metalled surface Over this a light priming coat of heated Spramex at the rate of 2 gallons per 100 square feet will be given. After the surface is treated as above, the coarse aggregate of approved quality shall be spread for filling the pot-holes, uneven surface and also for correcting cross-fall to 1 in 80 or superelevation and grade as required. The size of the aggregate shall be 1-inch to 2-inch gauge and roughly 16 cubic feet of metal should be used per 100 square feet of road-way. The aggregate shall then be dry rolled with a steam road-roller weighing not less than 10 tons. If any irregularities appear during or after rolling, they shall be corrected by loosening the surface and removing or adding additional coarse aggregate. Upon the partly rolled surface, asphalt of the required grade and quality shall be applied at the rate of 5 gallons per 100 square feet and the surface shall be covered with a thin layer of No. 2 metal so as to fill in voids and allow rolling of the sub-grade. The sub-grade shall then be rolled hard to correct camber and grade.

TWO AND A HALF-INCH ASPHALT MACADAM SURFACE.

After the surface is treated as above and after removing all loose and foreign matter, the coarse aggregate of the approved quality shall be spread upon the base in a uniformly loose layer of 3 inches, about 30 cubic feet of metal being used per 100 square feet. The size of metal shall be 1½-inch to 2-inch gauge. Every precaution shall be taken to prevent the aggregate from becoming mixed or coated with dust or other objectionable matter before and after spreading.

(*ii*) ROLLING.

Same as in Specification No. 1

(*iii*) FIRST APPLICATION OF ASPHALT.

(*a*) Upon the rolled coarse aggregate, asphalt of the required grade and quantity shall be uniformly applied at the rate of 11 to 14 gallons per 100 square feet as directed by the Engineer.

Paras (b), (c), (d) and (e). Same as in Specification No. 1.

(*iv*) FILLING SURFACE VOIDS WITH INTERMEDIATE AGGREGATE.

Same as in Specification No. 1

(*v*) SEAL COAT.

Same as in Specification No. 1.

(*vi*) PROTECTION OF BASE-COAT.

Same as in Specification No. 1.

SPECIFICATION No. 4.

CONSTRUCTION OF ROAD WITH CORROID MACADAM.

TWO COURSE CORROID MACADAM (SEMI-HOT PROCESS.)

Two and a Half-inch Consolidated Thickness with Liquid Seal Coat.

(i) MATERIALS USED IN MANUFACTURE.

The aggregate shall consist of selected granite, or other approved broken hard stone free from all foreign matter.

(ii) METHOD OF MANUFACTURE.

The aggregate shall be thoroughly dry, but its temperature shall not exceed 130 degrees Fahrenheit, when treated with the matrix, except in the semi-hot process where a temperature up to 280 degrees Fahrenheit is permissible. The temperature to which the composition shall be heated will depend upon the nature of the aggregate and the climatic conditions but shall not exceed 220 degrees Fahrenheit, except in the semi-hot process where temperatures up to 280 degrees Fahrenheit are permissible. The aggregate shall be thoroughly coated with composition in an approved type of mechanical mixer. The proportion of composition used will depend on the nature and grading of the aggregate.

(iii) FOUNDATIONS.

The road formation shall be well drained, and shall have the adequate foundation or thickness of Subcrust necessary to carry the maximum traffic likely to be imposed upon it. All loose material and foreign matter, particularly of an organic nature, shall be carefully removed and the surface shall be levelled and rolled to an even contour. It is considered essential that some form of lateral support be given to all roads surfaced with macadam

(iv) SPREADING, LAYING AND CONSOLIDATION.

The "Corroid" macadam shall be laid in one, two or three coats with a minimum thickness after consolidation of 2½ inches For a greater thickness than 2½ inches the material shall be applied in two or more coats. The cross-fall of the finished surface from the crown of the road to the channels shall not be more than 1 in 24, nor less than 1 in 36.

Every precaution shall be taken to prevent contamination of the macadam with dirt or foreign matter, both before and after spreading.

(v) SPREADING, ETC.

The macadam shall be evenly spread to the required contour, and shall then be rolled in a longitudinal direction from the sides to the centre of the roadway, with a roller between 8 and 12 tons, loaded. No rolling shall take place where the gas or water mains or sewer connections are less than 12 inches below the base subcrust, without the special instructions of the Road Authority.

When two-coat or three-coat work is being carried out, each coat shall be consolidated separately to the specified contour. Subsequent coats shall be laid as soon as possible after consolidation of the previous coat or coats.

When laying new material abutting on that previously consolitated, the older material shall be back to the full depth to give a clean face, and cross joints shall be formed in every case diagonally across the roadway.

After final consolidation, the surface shall be gritted with granite, or other approved hard stone chippings of ¾-inch or ½-inch to ¼-inch gauge and rolled.

It is advisable that all macadam surfaces receive within twelve months of completion, a surface dressing

(vi) "CORROID" COMPOSITION, GRADE 1 OR 2.

This should be applied at a temperature of between 200 degrees Fahrenheit and 300 degrees Fahrenheit by means of pressure distribution, gravity painting or any other approved method. The quantity will depend on the condition of the road. After application of the dressings, the surface shall be gritted with granite, or other approved hard stone chippings of ¾-inch to ½-inch gauge free from dust.

The surface dressing of single coat macadam shall be carried out as soon as practicable after consolidation.

TWO COURSE "CORROID" MACADAM (SEMI-HOT PROCESS) 2½-INCH CONSOLIDATED THICKNESS WITH LIQUID SEAL COAT.

AGGREGATE GRADING FOR BASE COURSE:

2-inch to 1-inch	..	60 %	22 cubic feet per 100 square feet.
¾-inch to ¼-inch	..	40 %	

Binder. "CORROID" Grade No. 3. Application temperature 260 degrees Fahrenheit. Quantity 2½ to 3 pounds per cubic feet of aggregate.

AGGREGATE FOR WEARING COURSE:

¾-inch to ½-inch	..	70 %	8 cubic feet per 100 square feet.
½-inch to ⅛-inch	..	30 %	

If the smaller grading contains little or no dust, reduce quantity and add stone dust filler 5 to 7½ per cent.

Binder: "CORROID" Grade No. 3 Quanity 4 to 5 pounds per cubic foot of the constituent grading.

LIQUID SEAL COAT.

Apply immediately, after completion of consolidation, using "CORROID" Grade 1 or 2. Quantity 24 pounds per 100 square feet. Application temperature not lower than 280 degrees Fahrenheit.

While the composition is still hot blind with ½-inch to ¼-inch clean dry chipping 2½ cubic feet per 100 square feet and roll immediately.

REMARKS:

No provision is made in this specification for the correction of surface irregularities or to secure correct camber, etc. The surface was brought to correct camber by water-bound macadam.

SPECIFICATION No 5.

TWO AND A HALF-INCH THICK PREMIXED ASPHALT MACADAM SURFACE.

(Without reconditioning Sub-grade).

(i) CLEANING.

The existing water-bound surface and especially the pot-holes and uneven surface, shall be thoroughly cleaned of all dust so as to expose metalled surface. Over this a light priming coat of heated Spramex (60 degrees Fahrenheit should be spread at the rate of 2 gallons per 100 spuare feet. This will be spread evenly with bass-brooms. Over the surface thus prepared, premixed asphalted metal should be spread for filling all pot-holes, inequalities and also for correcting cross-fall to 1 in 80. The size of the aggregate to be 1½-inch to 2-inch gauge and roughly about 16 cubic feet of metal to be used for 100 square feet of the roadway. The aggregate shall then be rolled with

a steam-roller weighing not less 10 tons. If any irregularities occur during or after rolling they shall be corrected by loosening the surface and removing and adding additional asphalted metal.

(ii) 2½-INCH THICK ASPHALT MACADAM.

The surface shall consist of two coats. The lower or the base-coat shall consist of ordinary blasted black trap road metal ½-inch to 1-inch size of approved quality graded in the proportion of 1 part of the former to 4 parts of the latter coated with bitumen heated to a temperature of 300 degrees Fahrenheit at the rate of 3½ to 4 pounds of bitumen per cubic foot of the stone aggregate mixed in the usual Mixing Machine prior to its being laid and spread to a depth of 3-inches. (If Burmah-Shell bitumens are to be used 2 parts of Mexphalt, 20-30 penetration, heated to a temperature of 300 degrees Fahrenheit, and 1 part of Shelmac would be best). About 30 cubic feet of aggregate shall be required for the base coat, but any additional quantity required on account of inequalities on the water-bound surface or for bringing the road to the required cross-fall, grade and super-elevation shall be used by the contractor without any extra cost. The wearing coat shall consist of ⅜-inch to ½-inch stone chips (4 parts of ½-inch metal and 1 part of ⅜-inch size) of approved quality coated with bitumen of the same mix as used for the base coat at the rate of 4 to 4½ pounds of bitumen per cubic foot of the stone chips mixed in mixer and spread to a thickness of 1-inch depth. The approximate quantity of aggregate required would be 10 to 12 cubic feet per 100 square feet. No extra payment will, however, be made for any increase in quantity for bringing to the finished surface to the required grade, cross-fall and super-elevations. The work will generally be in accordance with the specifications of Messrs. Burmah Shell and Company (Bulletin No. 3 of Shelmac) if their products are used. If products of another make are to be used, the general specification of carrying out work shall have to be got approved in the first instance from the Executive Engineer, Thana Division.

(iii) SEAL COAT.

After completion of the above work, traffic shall be allowed over the road for about a month. The surface shall then be brushed, cleaned and all dirt and foreign matter shall be swept off. Over it, a sealing coat consisting of hot Spramex (or equivalent product of other Company) heated to 350 degrees Fahrenheit and sprayed by the sprayer at the rate of ¼ gallon per square yard and metal grit of approved quality No. 1, i.e., ¼-inch to ⅜-inch size (4 cubic feet per 100 square feet) shall be spread and the surface rolled with an 8-ton steam road-roller. Strong wooden side forms with iron spikes shall be fixed to give side support to the base while being laid and shall be removed only after the wearing coat has been finished without any extra cost. The contractor shall have to fill in the side-width with hard murum and metal, as the asphalt work proceeds to avoid breaking of asphalt edges. The same specification shall apply to asphalt surface of other manufacture if quoted for by the contractor, the proportion being equal to those of the "Burmah-Shell" materials.

SPECIFICATION No. 6.

TWO AND A HALF-INCH THICK PREMIXED ASPHALT MACADAM SURFACE. (Reconditioned Sub-grade).

(i) CLEANING SURFACE.

Prior to laying the asphalt macadam surface the water-bound surface of the road shall be brushed and cleaned thoroughly to remove all dirt and foreign matter as required to the satisfaction of the Executive Engineer or his Assistant. There should be no moisture in the sub-grade and it should be allowed to dry completely.

(ii) TWO AND A HALF-INCH PREMIXED ASPHALT MACADAM

The asphalt macadam surface shall consist of two coats. The lower or the base coat shall consist of ordinary blasted black-trap road metal ½-inch to 1-inch size of approved quality graded in the proportion of 1 part of the former to 4 parts of the latter coated with bitumen heated to a temprature of 300 degrees Fahrenheit at the rate of 3½ to 4 pounds of bitumen per cubic foot of the stone aggregate mixed in the

usual Mixing Machine prior to its being laid and spread to a depth of 3 inches. (If Burmah-Shell bitumens are to be used, 2 parts of Mexphalt 20-30 penetration heated to a temperature of 300 to 400 degrees Fahrenheit and 1 part of Shelmac would be best). About 30 cubic feet of aggregate shall be required for the base coat; but any additional quantity required on account of inequalities on the water-bound surface or for bringing the road to the required cross-fall, grade and super-elevation shall be used by the contractor without any extra cost. The wearing coat shall consist of ⅜-inch to ½-inch stone chips (4 parts of ½-inch metal and 1 part of ⅜-inch size) of approved quality coated with bitumen of the same mix as used for the base-coat at the rate of 4 to 4½ pounds of bitumen per cubic foot of the stone chips mixed in mixer and spread to a thickness of 1-inch depth. The approximate quantity of aggregate required would be 10 to 12 cubic feet per 100 square feet. No extra payment will, however, be made for any increase in quantity for bringing the finished surface to the required grade, cross-fall and super-elevations. The work will generally be in accordance with the Specification of Messrs Burmah-Shell and Company (Bulletin No. 3 of Shelmac) if their products are used. If products of other make are to be used, the general specification of carrying out the work shall have to be got approved in the first instance from the Executive Engineer, Thana Division.

(*iii*) TOP-COAT.

Same as in Specification No. 5.

SPECIFICATION NO. 7.

ONE AND A HALF-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE.

The existing pot-holes or inequalities in the surface shall be filled with grouted metal of the required size and properly consolidated with steam road-roller.

The surface treated as above shall be brushed and cleaned with brushes so as to make it clean of all loose and foreign material.

After the surface is cleaned as above, Spramex heated to a temperature of 350 degrees Fahrenheit shall be spread over the surface with watering cans at the rate of 1/5 gallon per square yard or as directed by the Executive Engineer, and while the surface is still warm, specially broken metal 1-inch to 1½-inch size shall be broad-casted, over it at the rate of about 15 to 18 cubic feet per 100 square feet. Every precaution shall be taken to prevent the aggregate from becoming mixed or coated with dust or other objectionable matter before and after spreading.

The coarse aggregate shall then be dry-rolled with steam road-roller weighing not less than 10 tons. The rolling shall start longitudinally at the sides and proceed towards the centre of the pavement overlapping on successive trips at least one half of the width of the roller. The rolling shall be continued until part of the metal layer is pressed into the old surface and makes a proper bond with it. The compact surface shall possess a firm even surface and present a texture which would allow of uniform penetration of asphalt.

Upon the rolled coarse aggregate, asphalt of 30-40 penetration shall be uniformly applied at the rate of ¾ gallon per square yard or as directed by the Engineer. Application of asphalt shall be made by means of a pressure distributor or with hand-pouring pots. The asphalt shall be treated in kettles to secure uniform heating of entire contents and shall be brought to a temperature of 300 to 350 degrees Fahrenheit as directed by the Engineer. After the application of asphalt, and if practicable, while the surface is warm, a thin layer of dry intermediate aggregate consisting of ½-inch to ¾-inch metal shall be broadcasted over the treated surface in such quantity as to fill the surface voids and just cover the treatment. It shall then be broomed, if necessary, to break up lumps to produce a uniform covering after which the surface shall be steam-rolled until thoroughly compacted and inter-locked.

After the intermediate aggregate has been thoroughly rolled stiff, the surface shall be swept clean of all loose material and treated with second application of heated asphalt under the same conditions and in the same manner as previously specified except that the rate of application shall be 1/3 gallon per square yard or as ordered by the Executive Engineer. The central asphalt surface which has been left untreated shall also be given a final sealing coat of Spramex and grit after filling in pot-holes, if any.

After the application of asphalt, and if practicable while it is still warm, dry fine aggregate consisting of ¼-inch grit shall be broad-casted over the surface and rolled until thoroughly bonded to the road. As required, additional fine aggregate shall be spread and broomed over the surface during rolling in sufficient quantity to take up all excess of asphalt. The finished surface shall be uniform, free from ruts or irregularities in contour and true to the required grade and camber.

SPECIFICATION No. 8.

TWO-INCH SEMI-GROUT ASPHALT MACADAM.

The existing road surface shall be picked up and barrelled to the cross-falls of 1 to 40 or to such cross-falls as may be approved by the Executive Engineer, Thana Division, or his Assistant and to the required grade and super-elevation by an average 1½-inch thick layer of "Average" murum (i.e. 15 cubic feet per 100 square feet).

On the surface so barrelled, a layer of fresh blasted hard black-trap metal of approved quality and grade (1½-inch to 2-inch in size) shall be spread in a uniform layer of 4 inches (about 32 cubic feet of metal would be required per 100 square feet allowing for local hollows and depressions).

This shall be consolidated thoroughly with a 10 to 12-ton Steam Road Roller with profuse artificial watering as required till the hoggin rises to about ½ inch below the top of metal surface. Any inequalities in the cross-fall or grade or super-elevation shall be made by the addition or removal of metal as required before the final consolidation is over. The rate includes cost of metal and murum and labour in spreading them. In places where the thickness of surface to be spread is more than 4 inches, the consolidation shall be done in 2 layers to the satisfaction of the Executive Engineer or his Assistant

The reconditioned water-bound macadam surface must then be left over for a period of not less than 24 hours, or as the Executive Engineer desires, till the moisture in the sub-grade is absolutely evaporated. The surface during this period shall be properly maintained without any extra cost.

(*i*) BRUSHING.

Prior to the spreading of asphalt, the water-bound surface shall be swept very clean to remove all blinding materials so as to expose the metal surface.

The compacted course aggregate shall possess a fairly firm and even surface, true to the grades and cross-sections shown on the plans and present a texture which will allow a uniform penetration of the asphalt. If any irregularities appear during or after rolling, they shall be remedied by loosening the surface and removing or adding coarse aggregate as may be required after which the area disturbed including the surrounding surface shall be rolled until satisfactorily compacted to a uniform surface.

(*ii*) FIRST APPLICATION OF ASPHALT.

(*a*) Asphalt shall be applied only when coarse aggregate is thoroughly dry for its entire depth and is passed by the Executive Engineer or his Assistant.

(*b*) Upon the rolled coarse aggregate asphalt of the required grade (Socony 101 E Asphaltum) and quality shall be uniformly applied at the rate of 11 gallons per 100 square feet as directed by the Engineer.

(*c*) Application of the asphalt shall be laid by means of a Pressure Distributor or with hand pouring pots but preferably by the former.

(*d*) The asphalt shall be treated in kettles or boilers to secure uniform heating of the entire contents and shall be brought to a temperature of 300 degrees Fahrenheit as directed by the Executive Engineer. A thermometer must be provided to determine the temperature of the asphalt during heating or prior to application.

(e) Same as in Specification No. 1.

(iii) FILLING SURFACE VOIDS WITH INTERMEDIATE AGGREGATE.

After the first application of asphalt, and if practicable while still warm, a thin layer of dry intermediate aggregate consisting of ⅜-inch to ¼-inch metal shall be broad-casted over the treated surface in such quantity as to fill the surface voids and just cover the treatment. About 6 to 8 cubic feet of metal per 100 square feet is required. It shall then be broomed if necessary to break up all clumps and produce a uniform covering after which the pavement shall be steam-rolled until thoroughly compacted and inter-locked.

Suitable precautions shall be taken to prevent the distribution of the intermediate aggregate over portion of the coarse aggregate which has not received the application of asphalt and in no case shall it be dumped directly upon either the treated or untreated coarse aggregate. The surface shall then be left over for a period of nearly 24 hours and then allowed to be used by traffic.

(iv) SEAL COAT.

After the surface has been completely closed under traffic, it shall be swept clean of all loose material and treated with a second application of heated asphalt under the same condition and in the same manner as previously specified except that the rate of application shall be 4 gallons per 100 square feet.

If hand-pouring pots are used, the lines of distribution shall cross those of the first application at an angle of approximately 90 degrees. After the second application of asphalt, and if practicable while it is still warm, dry fine aggregate consisting of grit shall be broadcasted over the surface and rolled until thoroughly bonded to the road (quantity of grit per 100 square feet is 4 cubic feet). As required, additional fine aggregate shall be spread and broomed over the surface during rolling in sufficient quantity to take up all excess of asphalt.

Upon completion of the base-coat, however, only a very light uniform covering of loose aggregate shall be allowed to remain on the road. The finished surface shall be uniform, free from ruts or irregularities in camber and true to the required grade.

SPECIFICATION No. 9.

ONE AND A HALF-INCH THICK PREMIXED SHALIMAR TAR CARPET.

The stone metal should be of the best quality obtainable and tough. It must be clean and free of all foreign matter before coating.

(i) METHOD OF CONSTRUCTION.

(1) Base-Coat

(2) Preparing the Road Surface.

The road surface on which the carpet will be laid should be properly cleaned of all clay, dust, dung, and other matter, with hard and soft brushes, scrapers, small picks, etc. Immediately before laying the premix the surface will be paved with gunny bags to remove dust and dirt.

(ii) PREMIXING STONE METAL.

Stone metal as specified and thoroughly mixed in dry state should be placed in improvised mixing drums made from empty road tar drums, in measured quantities and High Viscosity Road Tar at the rate of 4 pounds per cubic foot of aggregate and heated to 260 degrees to 270 degrees Fahrenheit should be poured in and the aggregate and tar thoroughly mixed by revolving the drum until all particles are coated. It is of vital importance that the exact measured quantity of tar should be used for each batch. (If on account of cold, difficulty is experienced in mixing properly, the apparatus can be mounted on an iron lined platform on which the brazier can be placed under the drum. This is unlikely to be necessary in Bombay).

The premixed metal is then removed from the drum and at once without curing, spread evenly to specified thickness and camber on the road surface with trowels, forked kodalies, raked, &c. The premixed metal should then be rolled lightly (2 or 3 turns of the roller) and any depression or humps appearing should be rectified by adding or removing the premixed material.

(iii) TOP-COAT .

The chips of the top-coat are premixed in exactly the same way as described for the stone metal of the base-coat. It should then be spread evenly at the rate of 4½ cubic feet per 100 square feet.

The whole carpet should then be rolled to completion, *i.e.,* till all movement ceases.

After rolling is complete, (rolling of any section must be done in one day and not commenced on one day and completed the next day), it is possible to use the road 24 hours later, but it is preferable, if possible, to close the section to traffic, roll for 3 or 4 days and then open to traffic.

(iv) SEAL OR WEARING COAT.

It is a matter of visual observation to decide when to apply the seal coat. The correct time is, when the carpet has been rendered thoroughly compact by the action of the traffic and does not present at all an open surface (if the surface is still partially open, too much tar runs into the body of the carpet, and there is a danger of the chips of the seal coat not adhering sufficiently). This is dependant on the type of the traffic, and also whether the berms are of grass or soil. The minimum period is one month after compaction of the carpet, and it may be necessary to prolong this up to two or three months.

(*a*) The surface should be cleaned thoroughly as for painting. Where tar No. 3 is to be used, the temperature should be from 260 to 270 degrees Fahrenheit.

The hot tar is to be poured evenly over the surface at the rate of 33 pounds per 100 square feet; the chips at 4 cubic feet per 100 square feet, evenly spread at once and rolling of the chips to set should be done without delay (Rate of rolling that can be done is 16,000 square feet per diem).

QUANTITY OF MATERIAL REQUIRED FOR PREMIXED TAR CARPET FOR AN AREA 2 x 660 x 18.

1.	BASE-COAT.	
	1½-inch layer of metal, size 1-inch to 1-inch ..	2,740 c.ft.
	Of this 70% is 1½-inch to 1-inch ..	2,050 c.ft.
	and 30% is ¾-inch to ¼-inch ..	700 c.ft.
	High Viscosity Road Tar at 4 lbs. per c.ft.: 11,000 lbs ..	5.0 tons.
2.	TOP COAT.	
	½-inch to ⅛-inch chips at 4½ c.ft. per 100 s ft ..	1,070 c.ft.
	High Viscosity Road Tar at 4 lbs. per c.ft. ..	1.91 tons.
3.	SEAL COAT.	
	½-inch to ⅛-inch chips at 4½ c.ft. per 100 s.ft. ..	951 c.ft.
	High Viscosity Road Tar at 33 lbs. per 100 s.ft. ..	3.5 tons.

SPECIFICATION No. 10.

5-INCH THICK CEMENT CONCRETE ROAD.

Specification for one Course Portland Cement Concrete Road.

The contractor is advised to read carefully through this specification and include in his rate for all items of work mentioned in this specification which will be strictly adhered to.

A. MATERIALS.

Cement.

(Specifications for cement are to be detached when the supply of cement is controlled by Public Works Department

1. *Quality of Cement.*—The whole of the Portland Cement used on the works shall comply in every respect with the requirements of the latest British Standard Specification for slow setting of Portland Cement as issued and amended from time to time by the British Engineering Standards Association. The Portland Cement used in the works shall be manufactured in India.

2. *Tests.*—No other cement but that approved by the Executive Engineer will be allowed on the works and the contractor may not change his source of supply without the approval of the Executive Engineer in writing. The contractor shall produce test certificate to show that the cement is up to the specification and notwithstanding this, the Executive Engineer may at his discretion order that the cement delivered on the works and which he may consider of doubtful character for any reason whatever, must be re-tested by approved testers and fresh certificates of its soundness produced by the contractor and at his sole cost Cement ordered for re-testing shall be withdrawn from the works pending the result or re-testing.

3. *Packages.*—The cement shall be supplied in sound and properly secured and sealed bags, weighing 1 cwt. gross and containing 110½ to 110¾ lbs. of cement.

4. *Storage*—Large stock of cement shall not be kept at the works but only sufficient quantities to ensure continuity of the work. The contractors shall provide and maintain proper and efficient storage sheds for cement on the works. The floor of the store shall be raised at least 12 inches from ground and covered with Tarpaulin or any impervious material in order to protect the bags from moisture.

Cement which has been affected by moisture or in any way damaged shall be removed at once from the site. Cement shall be used in the order in which the consignments are received and not stored for an unduly long period.

Fine Aggregate.

5. *Quality of Sand.*—All the fine aggregate shall consist of clean, hard strong durable, uncoated and well-graded particles. When incorporated in the concrete mixture, the fine aggregate shall be free from frost, frozen lumps, injurious amounts of dust, mica, shells, soft or flakey particles, shale, alkali, organic matter, loam and other deleterious substances.

6. The sand shall be taken from a source approved by the Executive Engineer.

7. If the Executive Engineer considers it necessary, it shall be washed. The cost of washing must be included in the price for the concrete work.

8 In no case shall fine aggregate be accepted containing more than two per cent by dry weight, nor more than three and half per cent by dry volume, nor more than five per cent by wet volume, of clay, loam or silt. If any sample of fine aggregate shows more than five per cent of clay, loam or silt in one hour's settlement after shaking in an excess of water, the material represented by the sample will be rejected. If necessary, silt test may be taken by the Executive Engineer.

9. *Storage.*—All fine aggregate shall be stored on the works in such a manner as to prevent the intrusion of foreign matter.

10. All sand shall pass through a sieve having meshes not more than ¼ inch wide and if the Executive Engineer shall require it, it shall be screened before use at the expense of the contractor. Use of clean stone screenings can be allowed only at the discretion of the Executive Engin eer.

11. *Size.*—The fine aggregate shall conform as nearly as possible to the following sieve analysis:—

Retained on ¼-inch sieve	..	0 per cent
Retained on ⅛-inch sieve	..	25 to 30 per cent
Retained on No. 50 sieve	..	80 to 90 per cent
Retained on No. 100 sieve	..	96 to 98 per cent

A mixture which has the lowest possible void content shall be used.

12. This description of the fine aggregate shall not be interpreted as admitting the use of stone or slag screenings unless authorised.

Coarse Aggregate.

13. *Quality of course aggregate.*—The whole of the ingredients of the coarse aggregate shall consist of crushed rock, gravel or other inert material. The particles of course aggregate shall be clean, hard, tough, of durable material, free from vegetable or other deleterious substances and shall contain no soft, flat or elongated pieces. Aggregate, coated with stone dust, will not be allowed unless it is properly cleaned.

14. All coarse aggregate shall be stored on the works in such a manner as to prevent the intrusion of foreign matter.

15. If it is considered necessary, the Executive Engineer may order it to be washed and screened. The contractor shall also include in his price for concrete the cost of washing.

16. If screening is necessary, the cost shall be borne by the contractor.

17. *Grading of coarse aggregate.* —A mixture which has the lowest possible void content shall be used.

The coarse aggregate shall consist of :—

(1)	Metal No. 3, i.e. 1 inch to 1½ inch	..	Roughly 66.6 per cent.
(2)	Metal No. 2, i e. ¾ inch to 1 inch	..	
(3)	Metal No. 1, i.e. ½ inch to ½ inch	..	Roughly 33.3 per cent.

The whole of the aggregate shall all pass a screen having meshes not greater than 2-inches square and shall be retained on a screen having meshes ¼ inch square. The materials may be tested for voids before the work is commenced and at intervals during the coarse of construction as may be necessary, and the proportion of the different grades in the coarse aggregate fixed by the Executive Engineer so as to secure a well graded material varying from ¼ inch to 2 inches. The different grades of the coarse aggregate shall be measured by means of suitable boxes and in such proportions as may be approved by the Executive Engineer.

Water.

18. The water shall be reasonably clean and free from oil, alkali, organic or other deleterious substances. The quantity of water added to the materials for making concrete shall be properly under control and must be measured. If required, the contractor shall at his own expense, get the quality of water tested.

Reinforcement (whenever required).

19. *Steel fabric.*— B. R. C. No. 9 or equivalent fabric shall be used at such places as will be ordered by the Executive Engineer.

20. *Storage.*— When in storage on the works, the reinforcement shall be protected from corrosion by placing it on a dry platform under a weather-proofing cover.

21. *Quality of reinforcement.*—It shall be of the best quality of mild steel and shall be completely free from rust, paint, etc., before being actually used in the slab. It shall conform in every respect with latest rules of the L. C. C. for this item.

22. The contractor shall quote a separate additional rate per 100 square feet of road surface where extra reinforcement over and above the dowel bars and the longitudinal continuous bars at the central junction as shown in the plan, are to be used.

B. CONCRETE.

Ingredients and measurement of materials.

23. The concrete shall be composed of water, approved portland cement, fine aggregate and coarse aggregate.

24. All sand aggregate used on the works shall be carefully and accurately measured by volume in suitable gauge boxes and in quantities to the entire satisfaction of the Executive Engineer. The water should be added to the dry mix in a manner in which it can be properly controlled and measured.

25. The cement shall be measured by weight. One bag of cement weighing 110½ lbs. net shall be considered equal to 1.20 c.ft. in volume. Volumetric measurement of cement will not be permitted. If loose cement is used, it shall be weighed and 90 lbs. shall be considered as 1 c.ft. The contractor shall provide an accurate weighing apparatus on the work.

Proportion.

26. The proportions of cement, sand and aggregate for the concrete shall be 1 : 2 : 4 by volume and shall generally consist of the quantities as given below per bag of cement. The wooden measuring boxes should be filled in loose with the materials and not shaken or otherwise compacted. This proportion can however be changed at the discretion of the Executive Engineer according to the nature of the sub-grade.

Proportions of ingredients.	Quantity of materials per bag of cement.		
	Cement.	Sand.	Aggregate.
1 : 2 : 4	1 bag= 110½ lbs.	2.4 c.ft.	4.8 c.ft.

27. The maximum quantity of mixing water per sack of cement (110½ lbs.) shall be six gallons, which amount shall include the free water carried by the aggregates, but corrections shall be made to this quantity of water according to the wetness of the aggregates as per instructions of the Executive Engineer.

28. The proportion of concrete can be adjusted so as to give the most satisfactory mix, after ascertaining by tests the voids in coarse and fine aggregates. The proportion shall approximate to 1 : 2 : 3.75, subject to any adjustments considered necessary after the void test or mechanical analysis has been made.

Consistency and slump test

29. It is necessary that the concrete shall have the desired workability and give the maximum yield per bag of cement.

30. If the first batch is too stiff, either sand or coarse aggregate or both must be deducted until the desired workability is obtained. If it is too wet, either sand or coarse aggregate or both can be added as appears desirable, but under no circumstances shall the fixed water on tests be altered.

31. When the correct proportions have been ascertained, they must be carefully noted and adhered to until there is a change in the condition of materials supplied.

32. In order to test the consistency of the mixed concrete, slump test shall be made by the contractor when and where required by the Executive Engineer, and these slump tests shall be carried out in the following manner.

33. The test specimen shall be formed in the mould No. 16 gauge galvanized metal in the form of the lateral surface of the frustrum of a cone with the base 8 inches in diameter, the upper surface 4 inches in diameter and the altitude 12 inches. The base and top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be provided with foot-pieces and handles.

34. When the test is made at the mixture, the samples shall be taken from the piles of concrete immediately after the entire batch has been discharged.

35. The mould shall be placed on the flat non-absorbant surface such as smooth plank or slab of concrete and the operator shall hold the form firmly in places while it is being filled by standing on the foot-pieces. The mould shall be filled to about one-fourth of its height with the concrete which shall then be punned using exactly 30 strokes of ½ inch rod pointed at the lower end. The filling shall be completed in successive layers similar to the first and top struck off so that the mould is exactly filled. The mould shall then be removed by being raised vertically immediately after being filled. The moulded concrete shall then be allowed to subside until quiescent and the height of the specimen measured.

36. The consistency shall then be recorded in terms of inches of subsidence of the specimen during the test which shall be known as slump:

Slump = 12 inches—(minus) inches of height after subsidence.

37. The allowable slump for concrete in the road slab shall be between 1½ inches and 2½ inches.

38. *Machine mixing.*—The concrete shall be mixed in a batch mixture of approved type which will ensure a uniform distribution of the material throughout the mass so that the mixture is uniform in colour and homogenous. The capacity of the drum shall be such that only whole bags of cement are used in each batch. Mixing shall continue for at least two minutes after all materials including water are placed in the drum and before any part of the batch is discharged. The drum shall be revolved at not less than 14 nor more than 18 revolutions per minute. The drum shall be completely emptied before receiving materials for succeeding batch. The volume of the mixed material in each batch shall not exceed mixer manufacturer's rated capacity of the drum.

39. The drum shall be cleaned at frequent intervals while in use and shall be thoroughly washed out when mixing operations cease for any period longer than 30 minutes.

40. Suitable arrangements shall be provided for water-storage, water-measuring and time-measuring devices.

41. Mortar or concrete which has partially set shall not be retempered by being mixed with an additional material or water.

42. *Hand mixing.*— Hand mixing when allowed by the Executive Engineer, shall be carried out in the following manner, and shall be done on a water-tight platform or trough, at least 7 feet by 12 feet with three sides of sufficient depth to prevent the materials from being shovelled off during the operation of mixing. The actual mixing shall be carried out by two or more men opposite each other using square-ended shovels (not *Powras.*)

43. The specified quantity of sand for the batch of concrete shall be spread out first on the platform or trough, making a level heap about 6 inches deep, and on the sand specified quantity of cement shall be spread. All the dry sand and cement shall be turned over with shovels at least three times until the mixture is of uniform colour. Each shovelful should leave the shovel with a spreading action as well as a turning. The specified quantity of coarse aggregate shall now be added and the whole mixture turned over again at least three times. The specified quantity of water shall next be added slowly through a rose attached to a watering can while the process of turning the

mixture over is being carried out. The mixing shall be continued until the whole batch has reached an even consistency and the mortar is spread evenly through the batch.

44. The water must not be added from a bucket or *bhisti's* bag to the dry mixed materials.

After mixing the concrete must be placed immediately.

C. CONSTRUCTIONAL DETAILS.

45. A uniform section of 5 inches thickness as per plan, page 98, shall be adopted unless otherwise stated.

Preparation of sub-grade

46. The sub-grade shall be constructed to have as nearly as practicable, *a uniform bearing power throughout its entire width.* Whenever the sub-grade extends beyond the lateral limits of an old roadway, or wherever an old gravel, macadam or other hard compacted crust comes within 6 inches of the elevation of the finished sub-grade such old roadway or crust should be ploughed, loosened, or scarificed to a depth of at least 6 inches and the loosened material redistributed across the full width of the sub-grade, adding suitable material when necessary, so that when compacted to the required elevation, alignment and cross-section, the sub-grade will approach as nearly as possible a condition of uniform bearing power. Compression of the sub-grade material shall be accomplished with a roller weighing not less than 8 tons. Hand-tamping of portions of the sub-grade may be directed by the Executive Engineer, when necessary. There shall not be left on the sub-grade or shoulders, beams or ridges of earth or other materials that will interfere with the immediate discharge of water from the sub-grade to the side ditches, and the sub-grade shall be maintained free from ruts so that it will at all times drain properly.

47. All depressions developing under traffic on the sub-grade or in connection with rolling shall be filled with suitable material. Rolling shall be continued until the sub-grade is uniformly compacted, properly shaped and true to grade and alignment. It is not intended that rolling shall be continued beyond that point as the purpose of rolling is not to produce a sub-grade that cannot be further compacted but to produce *a uniformly compacted sub-grade.*

48. All hauling shall be distributed over the width of sub-grade so far as practicable, so as to leave it in an uniformly compacted condition.

49. All soft or spongy parts of the sub-grade shall be excavated and refilled with approved material well-tamped in 6-inches layers or efficiently drained by tiles or trenches filled with stones, whichever method the Executive Engineer shall decide.

50. *Checking and acceptance.*—Immediately prior to placing concrete on the sub-grade it shall be checked by means of an approved scratch template, resting on the side forms, having the scratch points placed not less than 8 inches apart and to the exact elevation and cross section for the sub-grade surface. The scratch template shall be drawn along the forms, so that the plan of the points will be at right angles to the grade line, and long axis of the template at right angles to the centre line to the road. All high places indicated by the scratch points shall be removed to true grade and any low places back-filled with suitable material and rolled or hand-tamped until smooth and firm. The sub-grade shall be checked and completed in accordance with the requirements for a distance of not less than 100 feet in advance of the concrete. If hauling over the sub-grade after it has been finished and checked as above specified, results in ruts or other objectionable irregularities, it shall be rolled again or hand-tamped and placed in a smooth and satisfactory condition before the concrete is deposited upon it.

51. No concrete shall be laid on the sub-grade until the sub-grade has been passed by the Executive Engineer.

Crossfall.

52. The cross-fall of the finished foundations shall be 1 in 60 as determined by the Executive Engineer.

53. *Waterproof paper.*—Road lining paper shall be spread on the sub-grade thus perpared to serve as an insulation layer.

Forms.

54. *Wooden forms.*—Wooden forms shall be dressed to 3 inches in thickness and equal in depth to thickness of the slab at the sides. Forms shall rest upon stakes driven into the ground with 1 foot of each end of each separate piece, and at intervals not greater than 5 feet elsewhere. Forms shall be held by stakes driven into the ground along the outside edge at intervals not more than 6 feet, two stakes being placed at each joint. They shall be firmly nailed to the side stakes and well braced at any point, where necessary, to resist the pressure of the concrete or the impact of the tamper. Forms shall be capped along the inside upper edge with 2-inch angle irons.

55. *Metal forms.*—Metal forms shall be of shaped steel section such as channels, etc. They should be at least 10 feet in length for tangents and for curves having radii (150 feet) and over. Smaller pieces upto 5 feet may be used for curves having radii less than 150 feet. The depth of the forms must be the same as the thickness of the slab and sufficient bracing-pins or stakes shall be used so as to prevent any displacement of form's due to pressure of concrete slab or impact of tamper.

56. *Setting forms.*—Forms shall be set to the exact grade and alignment at least 100 feet in advance of the point of depositing concrete. Before setting, the forms must be thoroughly cleaned. After setting, they shall be thoroughly oiled before concrete is placed against them. Forms in place will be subject to the check and correction of line and grade at any time.

57. It is essential that forms should be rigid as on this depends the even running of the finished surface.

58. No forms shall be removed until at least 24 hours have elapsed after the concrete has been deposited against them and every care should be exercised during their removal to ensure that the concrete is not in any way damaged. The forms shall be thoroughly cleaned before re-use.

Joints.

59. *Transverse expansion joints.*—Transverse expansion joints shall be spaced approximately 40 feet and 20 feet alternately or as shown on the plans. A bulkhead cut to the exact section of the road shall be securely stacked in place every 20 feet (*vide* No. 87 of S.E.R.D. of 25-4-39) at right angles to the centre line and surface of the road. The premoulded joint filler shall be placed against the bulkhead and held in position by pins on which there is an outstanding lug for subsequent lifting. Concrete shall be deposited on both sides of the bulkhead before it is removed. After the concrete has been struck off, the bulkhead shall be removed by lifting it slowly from one end and replacing it with concrete as it is lifted, so that the joint filler will be left in the correct position.

60. After the concrete has set sufficiently, the edges of the slab at the joint shall be rounded with a ¾ inch edging tool.

61. The joint filler should be wider than the slab depth and must extend to the bottom. It is advisable to notch the joint into the sub-grade by scratching a groove therein with a pick and setting the filler into the groove and tamping earth against it; the concrete is then placed on both sides and the bulkhead removed.

62. The premoulded filler shall be placed by a method which satisfies the Executive Engineer.

63 When the expansion joints are made at the end of the day's work, they shall be formed by finishing the concrete to the bulkhead, placed as before specified. When work is resumed, the joint filler shall be placed against the hardened concrete and held in position by pins until fresh concrete is placed against it.

64. Before the road is open to traffic, the joint filler shall be trimmed off to a uniform height of ¼ inch above the concrete surface and ironed down until flush with the concrete surface.

65. *Dowels.*—For steel dowels across transverse expansion joints, there shall be holes in the bulkhead spaced 2 inches centre to centre; 2 inches below the surface of the finished concrete through which ¾ inch plain round steel rods, 4 feet long, shall

be inserted with 2 feet projecting. At least one-half of each bar shall be completely encased in heavy paper or coated with a paint or oil in such a manner as to prevent a bond between the steel and the concrete and in addition some form of cap must be provided at the end of the bar to provide for sliding.

66. *Longitudinal Expansion Joints*— Longitudinal expansion joints shall be ordinary butt joints. The surface of the concrete should be oiled to prevent contact.

67. The edges of the slab shall be rounded with a $\frac{3}{8}$ inch radius edging tool.

68. *Transverse construction joints.*—These shall be formed whenever it is necessary to stop concreting for 30 minutes or longer, except at expansion joints by staking in place a bulkhead and finishing the concrete to the bulkhead. An edging tool shall be used along the bulkhead to make the construction joint a regular and well-defined line. (For steel dowels across transverse joints in this bulkhead, there shall be holes spaced 2 feet centre to centre, 2 inches below the surface of the finished concrete through which $\frac{3}{4}$ inch plain round steel rods 4 feet long shall be inserted with 2 feet projecting).

69. When work is resumed, the bulkhead shall be removed care being taken not to disturb the rods or the concrete. The fresh concrete shall be placed directly against the face of the concrete previously laid and carefully worked around the rods.

70. These constructional joints shall be avoided as far as possible.

71. *Longitudinal construction joints*—These shall be formed where required and must be straight and vertical. When so indicated on the plans, steel dowels of $\frac{3}{4}$ inch diameter bars shall be used as provided in clause heretofore.

72. After the concrete has set sufficiently, the edges of the slab at the joint shall be rounded with a $\frac{3}{8}$ inch edging tool.

Methods of construction.

73. The road shall be laid in alternate bays of 40 feet and 20 feet with expansion joints, properly filled with expansion jointing material every 120 feet. This should be $\frac{1}{2}$ inch broad.

Alternate bay method.

74. The concrete road slab shall be laid in the alternate bay system and of the cross sectional dimensions shown on the plans. The length of the bay shall be determined by the Executive Engineer to suit the nature of the joint and the method of tamping. Where tamping is done from the longitudinal side forms, the length of the forms may be increased to 30 feet at the discretion of the Executive Engineer.

75. The joints shall be plain butt joints at right angles to the longitudinal axis of the road

76. *Alternate bays.*—The Executive Engineer shall decide the order of laying the bays and also the time that shall elapse before commencing the intermediate bays.

77. *Surface finishing.*—All tools used and the method of use must be approved by the Executive Engineer before the work is commenced.

78. Screeding and tamping shall be carried out either from the transverse forms or from the side forms, as specified below, whichever the Executive Engineer shall decide.

79. After the operation of the screeding and tamping, the surface of the slab shall be floated longitudinally.

Placing concrete.

80. Concrete shall be placed only on a moist subgrade but there should be no pools of standing water. If the sub-grade is dry, it shall be sprinkled with as much water as it will absorb readily. It may be advisable to have the sub-grade sprinkled or thoroughly wet from 12 to 35 hours in advance of placing concrete, where such procedure seems necessary. This is not necessary where the road lining paper is used.

81. All operations from the time the mixing water is added to the completion of tamping, shall be completed within the setting time of the cement.

82. The mixed concrete shall be deposited rapidly on the sub-grade to the required depth, and for the entire width of the slab section in successive batches, and in a continuous operation without use of intermediate forms or bulkheads between joints. While being placed, the concrete shall be vigorously sliced and spaded with suitable tools to prevent formation of voids or honeycomb pockets. The concrete shall be especially well placed and tamped against the forms. When concrete is placed in two horizontal layers to permit the use of steel reinforcement, the first layer shall be roughly struck of a template or screed, riding on the side forms at the correct elevation to permit placing the reinforcement in the specified position. The concrete above the reinforcement shall be placed within 15 minutes after the first layer has been placed. Any dust, dirt or foreign matter which collects on the first layer shall be carefully removed before the upper layer is placed.

83. All concrete shall be transported from the mixer or mixing board to the place of final deposit by a method which will prevent segregation or loss of ingredients.

Placing reinforcements.

84. Steel fabric reinforcement of the size and weight shown on the plans and/or stated in the specification, shall be placed as shown, and parallel to the finished surface of the slab unless otherwise indicated. Fabric shall extend to within two inches of the sides and ends of slabs. All laps of fabric sections shall not be less than three-fourths of the spacing of members in the direction lapped.

D. SURFACE FINISHING.

Screeding and tamping.

85. The concrete shall be brought to the specified contour by means of a heavy screed or tamper fitted with handles weighing not less than 7 lbs. per cub. foot and not less than three inches wide. This screed or tamper may be of steel. It shall be shaped to the cross section of the slab and have sufficient strength to retain its shape under all working conditions. The tamper or screed shall rest on the side forms and shall be drawn ahead with a sawing motion, in combination with a series of lifts and drops alternating with lateral shifts of about an inch. At transverse joints, the tamper shall be drawn not closer than 3 feet towards the joint, and shall then be lifted and set down at the joint and drawn backwards away therefrom. Surplus concrete shall then be taken up with the shovels and thrown ahead of the joint.

86. Immediately after the screeding or tamping has been completed, the surface shall be inspected for high or low spots and any needed correction made by adding or removing concrete.

Hand floating.

87. The entire surface shall then be floated with a float board not less than 16 feet long and 8 inches wide. This float board shall have convenient plough handles at each end. It is operated by two men, one at each end, each man standing on a bridge spanning the road. The lower surface of the float board shall be placed upon the surface of the concrete with the long dimensions parallel to the centre line of the road. The float is then drawn back and forth in slow strokes about 2 feet long and advancing slowly from one side of the slab to the other. The purpose of this operation is to produce a uniform even surface on the concrete, free from transverse waves. The two bridges on which the workmen stand should be placed about 18 feet apart where the length of the float is 16 feet. When the entire width of the slab has been floated in this manner from the position of the bridges, they are moved about 12 feet, so that the next section to be floated overlaps the one previously so floated from three to four feet. After this floating has been completed and all transverse waves eliminated, the surface shall be finished by the belting process specified as under.

88. *Belting.*—The concrete shall be finished by using a belt of canvas, or rubber, not less than 6 nor more than 12 inches wide and at least 2 feet longer than the width of the pavement. The belt is to be applied with a combined crosswise and longitudinal motion. For the first application, vigorous strokes at least 12 inches long are used, and the longitudinal movement along the pavement is very slight. The

second application of belt should be immediately after the water sheen disappears, and the stroke of the belt should be not more than four inches and the longitudinal movement should be greater than for the first belting.

(Where concrete is laid in 10 feet strips, one belting will generally be sufficient, and finishing operations can be reduced usually to two screedings and one belting).

Brooming.

89. The broom shall be gently pulled over the surface perpendicular to the centre line of the road from edge to edge in such a manner that the corrugations will be uniform in depth and width. The sides of the slab and the joints shall not be edged until after the brooming process is completed.

90. This brooming shall be carried out immediately after the belt finish. The broom shall be of the leaf rake type with flexible prongs on a handle long enough to reach half way across the slab.

Finishing at joints.

91. A suitable float shall be used at all joints. The device shall be so arranged as to float the surface for a width of at least 6 inches on each side of the joint simultaneously, and shall be used in such manner as to produce a level surface across the joint. Edges of the slab at the sides shall be levelled for a width of 2 inches and the transverse edges of the slab at the joints should be rounded to ¼-inch radius.

Trueness of surface.

92. The finished surface of the slab must conform to the grade, alignment and contour shown on the plans. Just prior to the final finishing operation, the surface should be tested with a light straight edge 10 feet in length, laid parallel to the centre line of the road.

The maximum deviation allowed shall be ¼ inch in 10 feet.

Any deviation shall be immediately corrected.

Carborundum brick and water may be used to remove high spots.

Note.—The ideal concrete road surface should have a mosaic appearance, *i.e.*, the coarse aggregate is exposed and this can only be attained by reducing all finishing operations to a minimum and using as dry a mixture as possible.

E. CURING.

Protection.

93. Immediately after the final finishing operations, the surface of the concrete slab shall be covered with wet empty cement sacks and these shall be sprinkled with water in such a manner that the surface of the concrete will not be damaged, and must be kept continuously moist by sprinkling until the concrete has taken its final set.

Ponding.

94. As soon as it can be done without damaging the surface of the concrete, dykes or *bunds* shall be built along both edges of the slab with cross dykes at sufficiently frequent intervals and the surface flooded with sufficient water within the dykes to keep all portions of the concrete surface continuously covered with water for 14 days or as determined by the Executive Engineer after the concrete is laid. The ponded water shall be treated with diluted saponified cresol to prevent mosquito breeding. Two table-spoonfuls of saponified cresol shall be mixed with three gallons of water so as to make it an efficient larvacide.

Harding concrete surface.

(To be omitted by S. E. R. D.'s No. 87 dated 25-4-39)

95. A solution of Sodium Silicate shall be sprayed from a watering can and continuously brushed over the surface with a soft broom for several minutes to obtain an even penetration. Three applications shall be given in this manner allowing 24 hours to elapse between each, and the canvas cover shall be replaced on surface between each application.

96. The solution shall be in the proportion of one part of concentrated solution of P 84 sodium silicate to six parts of water and one gallon of solution shall cover 200 square yards.

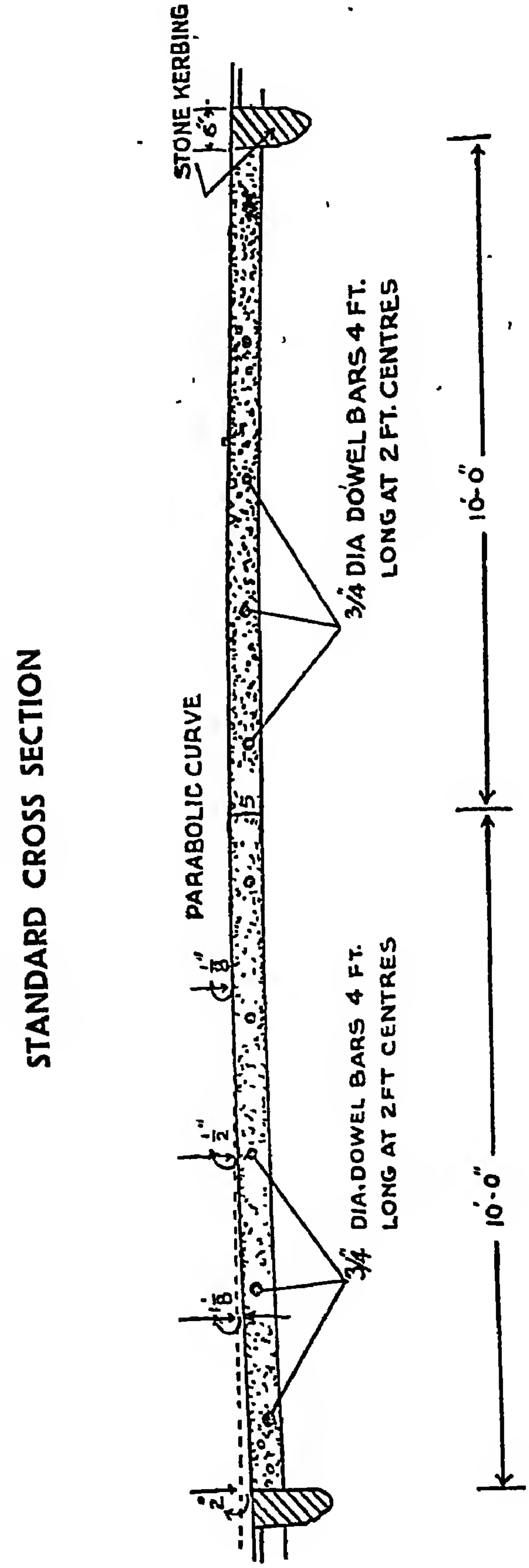
97. This solution may be applied either 14 days after the initial set or immediately after it. The surface of the concrete must be dry and free from dust before the application.

Cleaning.

98. After 14 days the earth or other cover may be removed and surface will be thoroughly washed, cleaned and allowed to dry.

Opening to traffic.

99 No traffic shall be allowed on the finished surface within 21 days of its completion. This period may be decreased or extended, if in the opinion of the Executive Engineer, the weather conditions, type of cement or other reasons justify a revision.


STANDARD CROSS SECTION
STONE KERBING
6"
PARABOLIC CURVE
3/4" DIA DOWEL BARS 4 FT. LONG AT 2 FT. CENTRES
3/4" DIA. DOWEL BARS 4 FT. LONG AT 2 FT CENTRES
10'-0"
10'-0"
1/8"
1/2"
1/8"
1/2"

SPECIFICATION No. 1.

TYPICAL CROSS-SECTION

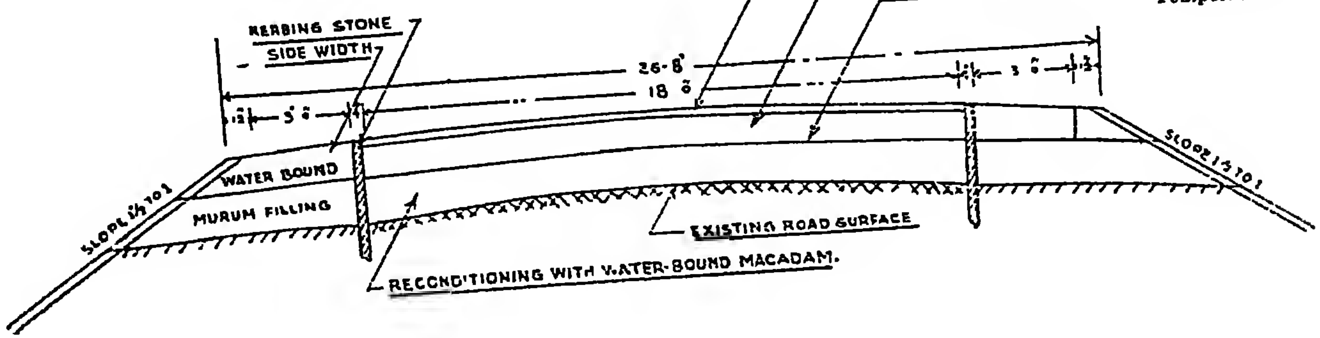
OF

3-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE

SEAL COAT:—Size of Metal .. .. .. 4 Cft.
Metal per 100 Sft. .. .. ¼ inch
Asphalt per 100 Sft. .. .. 5½-8 1/3 Gal.
Temperature of Asphalt .. .. 300°F-350°F.

3 IN ASPHALT MACADAM SURFACE:—Size of Metal 1½ to 2 inches
Metal per 100 Sft. .. .. 30 Cft.
Asphalt per 100 Sft. .. .. 13 to 17 Gal.
Temperature of Asphalt .. .. 300°F-350°F.

PRIMING COAT OF SPRAMEX:—Spramex per 100 Sft. 2½ Gal.
Temperature of Spramex .. .. 160°F.



SPECIFICATION No. 2.

TYPICAL CROSS-SECTION

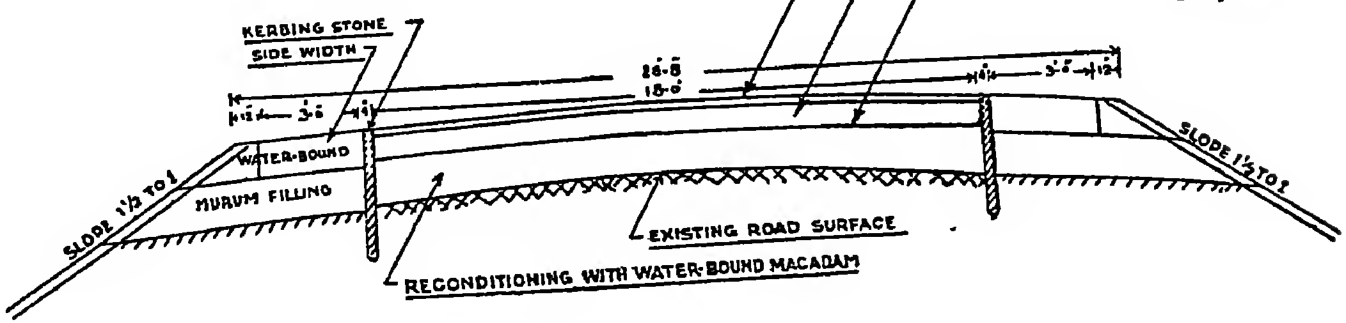
OF

2-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE

SEAL COAT:—Size of Metal .. .. .. ¼ inch
Metal per 100 Sft. .. . 4 Cft.
Asphalt per 100 Sft. .. .. 5½ to 8 1/3 Gal
Temperature of Asphalt .. .. 300°F-350°F.

2 IN. ASPHALT MACADAM SURFACE:-Size of Metal 1½ to 2 inches
Metal per 100 Sft. .. .. 24 Cft.
Asphalt per 100 Sft. .. .. 9 to 12 Gal.
Temperature of Asphalt .. .. 300°F-350°F.

PRIMING COAT OF SPRAMEX:—Spramex per 100 Sft. 2¼ Gal.
Temperature of Spramex .. .. 60°F

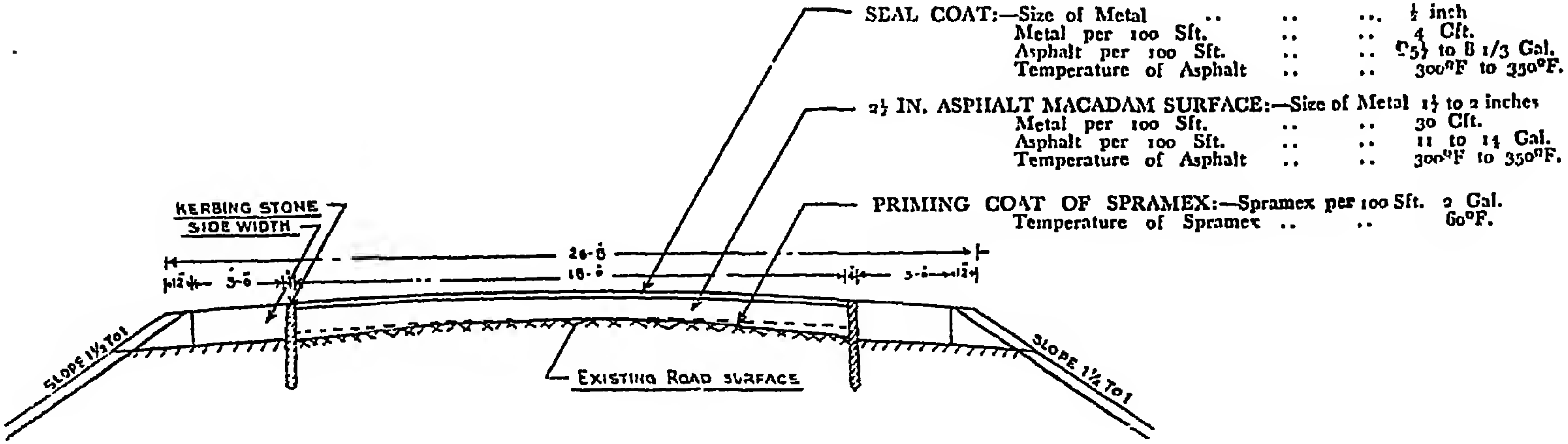


SPECIFICATION No. 3.

TYPICAL CROSS-SECTION

OF

$2\frac{1}{2}$-INCH THICK FULL-GROUT ASPHALT MACADAM SURFACE



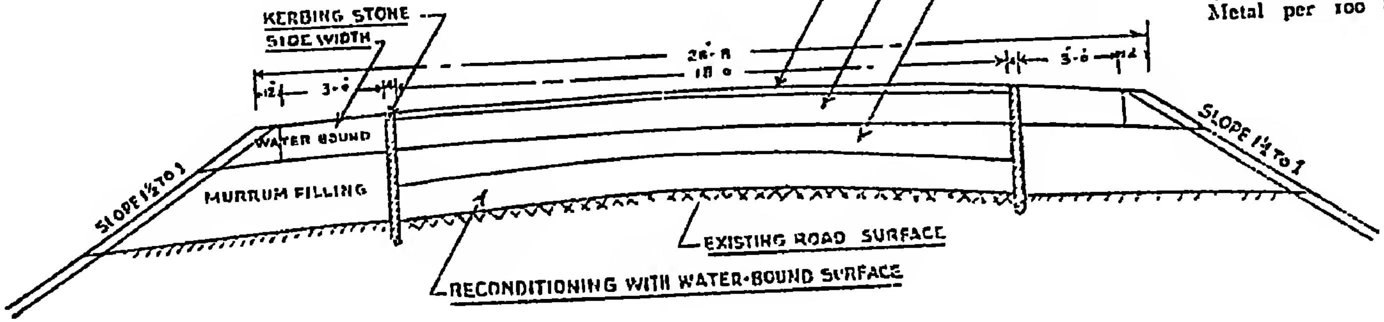
SPECIFICATION No. 4.

TYPICAL CROSS-SECTION

OF

2½-INCH CORROID ROAD SURFACE.

LIQUID SEAL COAT —Size of Metal	..	½ inch to ¼ inch
Metal per 100 Sft	..	2½ Cft.
Corroid per 100 Sft.	.	24 Lbs.
Temperature of Corroid	..	280°F.
1½ IN. WEARING COAT:—Size of Metal		¾ inch to ½ inch
Metal per 100 Sft.	..	8 Cft.
Corroid per 100 Sft.	..	32 to 40 Lbs.
Temperature of Corroid	..	260°F.
2½ IN. BASE COAT:—Corroid per 100 Sft.		55 to 66 Lbs.
Temperature of Corroid	..	260°F.
Size of Metal		2 inches to ¾ inch
Metal per 100 Sft.	..	22 Cft.



SPECIFICATION No. 5.

TYPICAL CROSS-SECTION

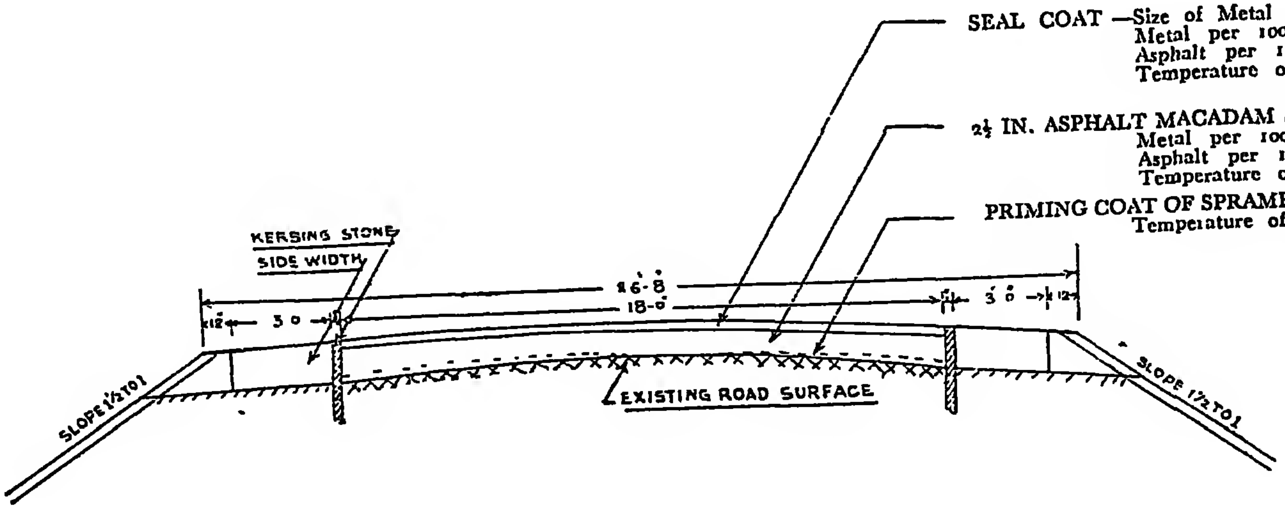
OF

2½-INCH PREMIXED ASPHALT MACADAM SURFACE.

SEAL COAT —Size of Metal .. .. .. ½ inch
Metal per 100 Sft. .. .. 4 Cft.
Asphalt per 100 Sft. .. .. 3 Gal.
Temperature of Asphalt .. .. 350°F.

2½ IN. ASPHALT MACADAM SURFACE- of Metal 1½ to 2 inches
Metal per 100 Sft .. .. 16 Cft.
Asphalt per 100 Sft. .. .. 11 Gal.
Temperature of Asphalt .. .. 300°F to 400°F

PRIMING COAT OF SPRAMEX: Spramex per 100 Sft. 2 Gal.
Temperature of Spramex .. 60°F.



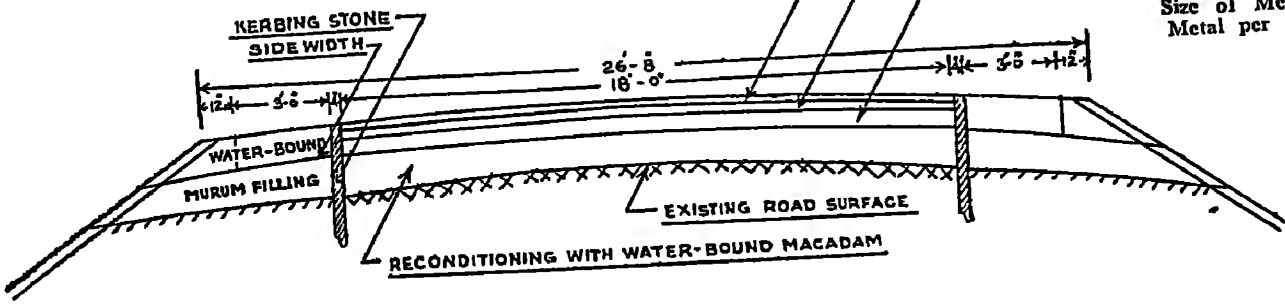
SPECIFICATION No. 6.

TYPICAL CROSS-SECTION

OF

$2\frac{1}{2}$-INCH PREMIXED ASPHALT MACADAM SURFACE.

SEAL COAT:—	Size of Metal	$\frac{1}{4}$ inch
	Metal per 100 Sft.	4 Cft
	Asphalt per 100 Sft.	3 Gal.
	Temperature of Asphalt	350°F.
ASPHALT MACADAM SURFACE:— (WEARING COAT)	Size of Metal	$\frac{3}{4}$ inch to $\frac{1}{2}$ inch
	Metal per 100 Sft. .	10 to 12 Cft.
	Asphalt per 100 Sft. . ..	40 to 45 Lbs.
	Temperature of Asphalt	300°F.
BASE COAT·—	Asphalt 100 Sft. ..	120 Lbs.
	Temperature of Asphalt .. .	300°F.
	Size of Metal	$\frac{3}{4}$ inch to 1 inch
	Metal per 100 Sft. ..	30 Cft.

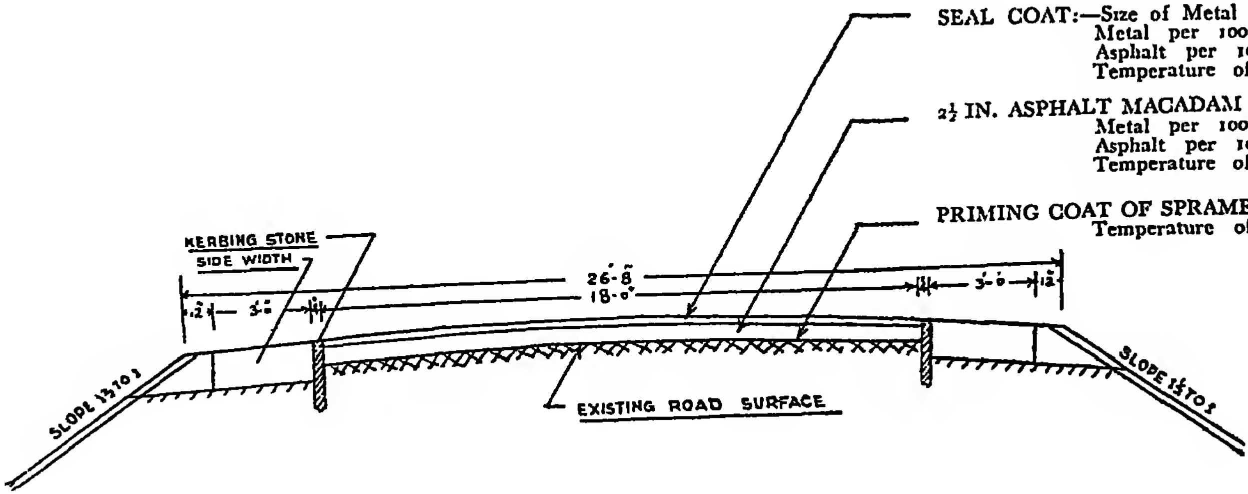


SPECIFICATION No. 7.

TYPICAL CROSS-SECTION

OF

1½-INCH FULL-GROUT ASPHALT MACADAM SURFACE



SEAL COAT:—Size of Metal .. .. .. ¼ inch
Metal per 100 Sft .. .. 4 Cft
Asphalt per 100 Sft. .. .. 4 Gal.
Temperature of Asphalt .. .. 300°F to 350°F.

2½ IN. ASPHALT MACADAM SURFACE·—Size of Metal 1 inch to 1¼ inch
Metal per 100 Sft .. .. 15 to 18 Cft.
Asphalt per 100 Sft .. .. 9 Gal.
Temperature of Asphalt .. .. 300°F to 350°F.

PRIMING COAT OF SPRAMEX:—Spramex per 100 Sft. 2.5 Gal.
Temperature of Spramex .. .. 350°F. to 400°F.

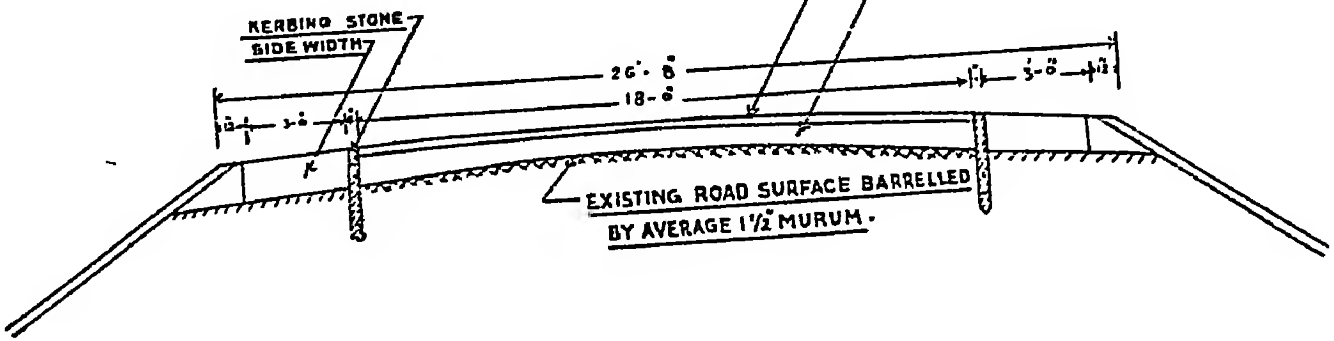
SPECIFICATION No. 8.

TYPICAL CROSS-SECTION

OF

2-INCH SEMI-GROUT ASPHALT MACADAM SURFACE

SEAL COAT:—Size of Metal	.. .. ..	½ inch
Metal per 100 Sft.	.. ..	4 Cft.
Asphalt per 100 Sft.	.. ..	4 Gal
Temperature of Asphalt	.. ..	300°F to 350°F.
2 IN ASPHALT MACADAM SURFACE —Size of Metal		1½ to 2 inches
Metal per 100 Sft.	.. ..	32 Cft.
Asphalt per 100 Sft.	.. ..	11 Gal.
Temperature of Asphalt	.. ..	300°F to 350°F.



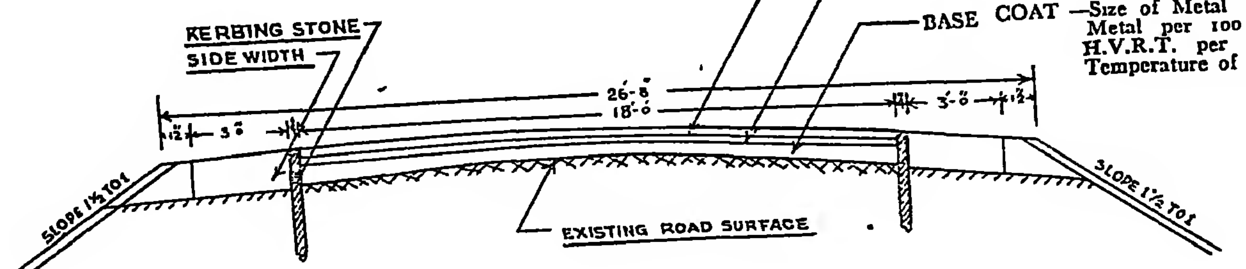
SPECIFICATION No. 9.

TYPICAL CROSS-SECTION

OF

1½-INCH PREMIXED SHALIMAR TAR CARPET

BASE COAT:—	Asphalt 100 Sft.	½ inch to ⅛ inch
	Metal per 100 Sft.	4½ Cft.
	H.V.R.T. per 100 Sft.	33 Lbs.
	Temperature of H.V.R.T.	300°F to 350°F.
TOP COAT:—	Size of Metal	¼ inch to ⅛ inch
	Metal Per 100 Sft	4½ Cft.
	Temperature of H.V.R.T.	260°F to 270°F.
	H.V.R.T. per 100 Sft.	18 Lbs.
BASE COAT—	Size of Metal	1½ inch to 1 inch
	Metal per 100 Sft.	12 Cft.
	H.V.R.T. per 100 Sft	48 Lbs.
	Temperature of H. V. R. T. ..	260°F to 270°F.

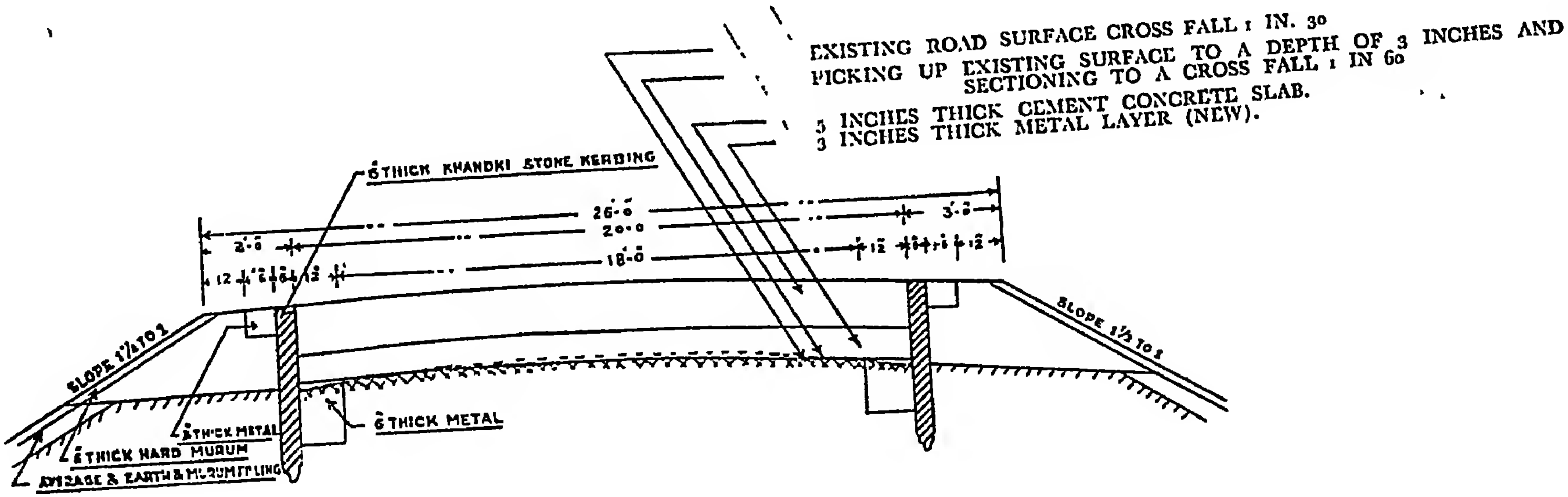


SPECIFICATION No. 10

TYPICAL CROSS-SECTION

OF

5-INCH CEMENT CONCRETE ROAD SURFACE



APPENDIX III

INTRODUCTION OF AND DISCUSSION ON WORKS VISITED BY DELEGATES DURING THE SIXTH SESSION OF THE INDIAN ROADS CONGRESS, BOMBAY, DECEMBER 1939.

The delegates assembled at the Conference Hall, 'Electric House' at 11 a.m. on 7th December. After expressing the pleasure of the Council at the record attendance and announcing some important alterations to the details of the previously circulated programme of visits, Mr. K. G. Mitchell, C.I.E., I.S.E., the President, called on Messrs. N. V. Modak, R. A. Fitzherbert and G. D. Daftary, in turn, to give a preliminary explanation of the works which the delegates were going to visit during their tour through the jurisdictions of these officers.

Mr. N. V. Modak, City Engineer, Bombay Municipality, introducing the notes on works in Bombay City said that the general policy of the Bomaby Corporation with regard to the road construction after the Great War (1914-18), was to finance road programmes from loans and to meet the interest and sinking fund charges from year to year from normal revenues by reducing expenditure on maintenance. The type of construction for a particular road was chosen on the consideration of the volume and the nature of the traffic that it carried, particularly the latter. Roads carrying more than 5,000 tons per yard width a day were constructed with, what he called, the 'permanent modes of construction'. For traffic seventy per cent. of which consisted of bullock carts and lorries, stone sett paving was used. Where this proportion was about thirty to forty per cent., sheet asphalt was provided and if it was still less, full grouting or semi-grouting or surface dressing was used.

Mr. Modak further explained that the work of road construction and maintenance in the city of Bombay presented a peculiar problem as their roads had to accommodate numerous public utility services. Urgent repairs to some of these services sometimes necessitated frequent opening up of road surfaces. Nearly one sixth of the entire road surface, on the average, was thus opened up every year due to the public utility services, and the Corporation had to spend no less than 25 lakhs annually for the restoration of trenches. Then there was the rainfall, which had to be dealt with. The drains were designed for a run off of 1 inch per hour but sometimes the rains were as heavy as 4 to 5 inches per hour. Bombay, he proceeded, was not favourably situated in the matter of outfall of drains which got tide-locked, when the high tide synchronised with heavy rainfall. It was not possible to raise the drains because of the low plinths of some old buildings. These, he said, were peculiar problems which did not face the Engineers of the Public Works Department.

As regards road widths, even 100 feet was not adequate for the requirements of Bombay traffic in certain areas, whereas the Municipal Act prescribed a *minimum* road-width of 40 feet only. The minimum, he opined, ought in no case be less than 50 feet *viz.*, a 36 feet carriageway and 7 feet footpaths on either side.

He said that they were now trying to improve the layout by providing traffic islands, pedestrian refuges, car parks and central reservation for tramtracks on wider roads. They may have to provide separate cycle tracks in the near future as the congestion due to 300,000 cyclists in Bombay and the number of accidents due to them was constantly on the increase. Marine drive was an example of their latest design. There was, he said, an Advisory Committee which made suggestions for improvements from the point of view of both traffic and development.

Mr. Modak concluded after mentioning very briefly the works that the delegates would be visiting.

Mr. R. A. Fitzherbert, Superintending Engineer, Central Circle, Poona, introducing notes on works to be visited in and around Poona, gave the delegates a few facts concerning the ghat section of the Bombay-Poona Road which he said was subjected to severe climatic conditions, the average annual rainfall being 180 inches. A water-bound macadam surface could, therefore, not stand and it was decided in 1937 to adopt the type of surface which was named 'Conphalt', consisting, as its name implied, of a central 9 feet wide strip of asphalt for fast moving traffic, and 7½ feet wide concrete side widths 7″-5″ section, for bullock carts. In 1938, however, the proposals were revised and it was decided to have a 20 feet wide all concrete surface of 5 inches uniform thickness, with 2 feet wide waterbound macadam side widths. The type, which they were laying down, he said, was easier to construct but had not the advantage of segregating traffic which the former type had.

The laying of concrete was originally commenced by hand-tamping. It was now being done by the road making machine which the delegates would be seeing at work. The machine had not worked long enough to allow its advantages over manual labour being precisely assessed, but it was already evident that, if an adequate supply of concrete could be maintained, the road slab could be laid more quickly with the machine. The machine, he said, took only 25 minutes to lay a 35 feet bay 10 feet wide as against 30 minutes taken by manual labour.

Mr. Fitzherbert then quoted from an Article in the August 1939 Number of the Indian Concrete Journal, which is an extract from the report of the Ministry of Transport in England :—

> "There is very little definite information available which will enable a true comparison to be made between the costs of hand and machine-finished concrete road. Even if comparable figures could be obtained from abroad, the labour conditions in this country are so different that the figures would be of very little use.
>
> The limited information available from machine-made roads in this country indicates that the cost is not likely to be appreciably different from the cost of hand-placed concrete. On works of considerable magnitude, however, the comparison would almost certainly be in favour of machine-placing ..... without taking into account possible savings in cement and the advantages accruing from the use of better quality concrete".

A summary of English experience shows that :

> "(1) Concrete of a consistence usually adopted for hand-placing is not increased in strength or density by machine consolidation.
>
> (2) The use of drier concrete increases the compressive and flexural strengths when the concrete is adequately consolidated by machine
>
> (3) The density of the dry concrete compacted by machine is of the same order as that of hand-tamped work..... ."

That he said, indicated that the increased strength of the concrete was due to the lower water-cement ratio which could be used. As their work had been carried on in the monsoon, with damp sand and soil, this ratio, he said, could not till then, be ascertained.

The rate of hand-tamped concrete worked out to Rs. 26/8/ per hundred square feet. The use of the machine having been made for a few furlongs only, a correct working rate had not so far been arrived at.

Mr. G. D. Daftary, Superintending Engineer, Northern Circle, Bombay then introduced the notes on various types of road construction adopted on the two main trunk roads in Thana Division of the Bombay Presidency namely the Bombay-Agra Road and the Bombay-Poona Road. He said that in a length of about 20 miles, ten* different specifications and four different cementing materials had been used. Asphalt had been used in seven places, "corroid" and Shalimar Tar in two places and cement in one place. The aggregate had been obtained from machine-crushed trap-rock and the thickness had been varied from $1\frac{1}{2}$ inches to 3 inches in full and semi-grout processes and from $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches in premixed ones, depending on the intensity of traffic, the condition of sub-grade and on other local considerations. For cement concrete road slab the thickness had been kept 5 inches.

Work had been done at one of the places in 1929. All other portions had been constructed from 1933 to 1939. With minor repairs all the miles had stood fairly well under heavy modern traffic, of intensity varying from 400 to 1500 tons per yard width of road surface per day with an average annual rainfall of 125 inches.

The cost of the works varied from Rs. 13/- to Rs 26/- per hundred square feet.

In conclusion, Mr. Daftary left it to the delegates to form their own opinions as to which type they considered most suitable, when they had visited the works.

The delegates then proceeded to visit the works, details of which are given in Appendix II (*vide* pp. 24 to 109).

The delegates assembled at the Conference Hall, Electric House, Bombay at 11 a.m. on Monday, December 11, 1939 for discussion of works visited with Mr. R. A. Fitzherbert in the chair.

Mr. K. G. Mitchell (President) :—Before we start, I have one or two things to say. The first is, that some people have asked whether it will be possible to have a demonstration of the earth road machinery which is on view outside. Whether such a demonstration is possible or not I cannot say at short notice, but Messrs. Volkart Brothers are showing a film of the working of the machinery this evening at 6 o' clock in a room in the Cricket Club of India. It cannot be before 6 o' clock, because there is difficulty in getting a place sufficiently dark for the purpose of showing the film. I hope some of you at least will be able to see the film.

There is one other thing. It was not possible for those persons who went on the morning trip to the Vihar Lake and on the afternoon trip to the Elephanta Caves yesterday to express formally our extreme gratitude to

* For a comparative statement of the quantities of materials used in the different specifications and their respective costs, see the statement facing page 72.

Mr. Nurmahomed Chinoy for his excellent hospitality. They were both pleasant trips, and the organisation was perfect. It must have involved a good deal of trouble for Mr. Chinoy—or, perhaps I should say that he does it naturally and efficiently, without any trouble.

I now move a very hearty vote of thanks to Mr. Chinoy for his very kind hospitality. (*Carried with acclamation*).

Mr. R. A. Fitzherbert (Chairman):—Gentlemen, we will start with the notes of Mr. Modak's works in Bombay. Members will ask questions, and then finally he will answer them. We shall take up the Poona visit next, and Mr. Kynnersley has very kindly offered to answer questions about the concrete machine; as regards other questions in connection with the asphalt section, I will do my best to answer them myself. And finally, we shall take up Mr. Daftary's roads in the Northern Circle, and he will answer the questions which relate to those roads.

Now, Mr. Modak's works; after all the members who wish to put questions have done so, Mr. Modak will answer them.

Rai Sahib Lala Fateh Chand (Bijnor):—The first point that I would refer to is about sheet asphalt. I found there were different types of construction favoured in different places. Once people take to one type of construction, they stick to it. Thus, while in the United Provinces, we found cement concrete leading the way, in Calcutta, it was grouting which was popular, in Hyderabad premix, and in Bombay we find sheet asphalt. The process followed in Bombay gives probably the same strength, as the stone ballast grouted or premixed. It makes the surface more smooth but the cost is much greater. My question is. Is it not possible to use stone ballast and to give only half-inch or three-quarter-inch top surfacing as usual with asphaltic material under the traffic conditions in Bombay?

Another point is: you give $7\frac{1}{2}$ inches of cement concrete foundation; is it a necessity? In the United Provinces we have been trying 3 inches of cement concrete on top of metalled surface. Will that not save a lot of money and will it not give a stronger surface than sheet asphalt? From what we have seen in Calcutta and Hyderabad, it appears that for bullock cart traffic cement concrete is best suited and that it has stood the test. In the United Provinces, we have also used it along the sides for bullock carts, with asphalted surface in the centre for motor cars. For motor cars perhaps asphalt roads are better, and for bullock carts cement concrete roads are better. So, the Indian Roads Congress should lay down some sort of specification for each kind of traffic—for instance, cement roads for bullock cart traffic, asphalt roads for motor traffic, and so on.

Another point is about cement pavements. We noticed that where the cement pavements had been made at site, there were no cracks. On page 36 of the notes it is said that the pavement laid *in situ* appears to be more durable than the precast slab. It has to be made clear as to which of the two types is to be adopted in future.

The same difficulty about cracks we found in the United Provinces as here; cracks develop most where there are manholes In practically 90 per cent. of the cases we noticed that there were cracks starting from one of the manholes for pipes. I would like to know a suitable method of preventing these cracks.

As regards repairs, we found that a three-inch road crust was being taken off and thrown away. It contained a good deal of asphalt and must have been constructed at some expense. Asphalt dealers say that their asphalt should stand for a number of years, but we found that costly material being rejected. Perhaps Bombay engineers might try to make some use of it by heating it again and mixing some such material as will restore its original strength, and using it at least over the sub-grade. That will mean a great deal of economy in road maintenance. The machine that was being used was cutting only half an inch. Thus a large amount of money had to be spent in simply cutting that half an inch of surface in addition to what was spent in laying it. I would like to know whether it was not possible to add a layer to the existing surface. That would not have added much to the camber of the road.

Another point is about crossings. We found in Calcutta that in addition to the traffic police, there were traffic islands. Here in Bombay we find that there is no traffic police in addition to traffic islands, and it is often dangerous to cross at junctions and at points like the Band Stand on Queen's Road. If traffic lanes are put in the same way as they are put for entering the main road from the side roads, it might perhaps help.

About lights, it has been said that gas lights are cheaper. Is it a speciality for Bombay ? Or can this be tried in other places too ?

These are the points on which I would like to be enlightened.

Mr. N. Durrani (Madras):—During the course of our visits, I was told that traffic censuses were taken only once a year, and that too, for about two days only. I think this will not depict a true picture of the actual state of affairs. The traffic census may have to be taken at least twice a year and for a week each, at a time when traffic intensity is heaviest A clear record of traffic census must also be maintained for up and down traffic as one half of a road may warrant a more expensive surfacing than the other. During the course of inspection, I found one side of a road more heavily tracked than the other The different grades of traffic census also require precise definition like the grades of, say, Mobiloil.

A tabular statement of various methods of surfacing with detailed specifications, traffic census, nature of soil, condition of weather and condition of surface at fixed intervals of time and the amount required for first cost and subsequent maintenance may be given. With this data, it will be easy to pick the right type of surfacing under any given conditions. 'Hit and Miss' methods will not then have to be tried involving large sums of money.

My personal opinion is that mass concrete 1 : 2 : 4 of 6 inches average thickness is un-economical. Instead, I suggest 4 inches of $1\frac{1}{2}$-inch metal 1 : 3 : 6 and 2 inches of $\frac{1}{4}$ inch to $\frac{1}{2}$ inch 1 : 2 : 4 wearing coat with tell-tale rods. The riding surface can thus be renewed from time to time, whereas in the first method of mass concrete 6 inches thick, it is not possible. This will also be more economical.

Mr. G. B. Vaswani (Karachi) :—Those of you who were present at the last Congress at Calcutta will remember that it was my suggestion that time should be allotted for discussion on Inspections and today it is an accomplished fact for which we are all thankful to the President.

I shall speak now on first day's inspection of Bombay roads held on the 7th December, 1939.

As a Municipal Engineer, I am more interested in Municipal roads than I think most of you are, as in this Congress, representation of Municipal Engineers is in hopeless minority.

I will divide the inspection in five parts :—

1. Traffic Islands,
2. Car Parks,
3. Marine Drive,
4. Works,
5. Machinery.

As regards Traffic Islands, you will agree with me that they are necessary and on account of increase in vehicular traffic are to be provided.

It must have been observed that the big traffic Islands are situated in big squares round about King's Statue, Flora Fountain, Band Stand and so on.

It is a well known fact that these public places are usually visited by the residents and outside public and in fact they are the 'lungs' of the locality where people of thickly populated areas come to breathe fresh air. Is it advisable to provide car parks in such places? Would it not have been better if these squares had been covered with nice lawns and beautiful flower beds and provided with benches for seating ?

Imagine for a while the area round the Band Stand decorated as stated above, with ladies and children occupying the benches and children dancing to the tunes of the Band and compare it with the present condition of the Square covered with motor cars and chauffeurs and deserted by the gentry. Which one would you like ?

The Band Stand area has been newly developed. Could not a separate car park be provided outside this Traffic Island ?

As regards Marine Drive, it is a very beautiful road constructed on modern lines. It appears that one thing is omitted in design which is the provision of space for car parks.

Another point in this road which has struck me and to some of you is, the steep camber of 1 in 40 given to the road which is of cement concrete. It will be interesting to know the reason for giving such a steep camber.

The third thing which invites attention of all is the distances at which the vehicular crossings have been provided in Marine Drive In one length at least, the crossing is too far off. For mere crossing to the other

side of the road, the car has to travel very long distances, which in other words, means unnecessary loss of petrol. I am of opinion that nearer crossings would have been better for the convenience of the vehicular traffic and would have been appreciated by the public.

Now I come to the Sea-Wall. It consists of loose rubble embankments very wide—(58′ 6″) at the bottom and 20 feet at the top, over which has been placed 16 feet wide wall to support the parapet wall and the footpath pavement. Could not a masonry wall of small width be provided at a cheaper cost than the above ?

On 45 feet wide Marine drive footpath, we saw that blue stone pavement was provided in 10 feet width from the kerb and the rest upto parapet wall on sea-side was of plain cement concrete. The cost of blue stone pavement was Rs. 65/- per hundred square feet and that of plain concrete Rs. 33/- per hundred square feet. The heavy pedestrian traffic was on the sea-side and was carried by the cement concrete. Then where was the necessity of providing blue stone pavement at a cost double that of the cement concrete pavement.

As regards the road works, you must have observed that most of the roads are provided with sheet-asphalt pavement on cement concrete foundations, which is only possible for a rich Corporation like Bombay. They construct roads from the point of view of their permanency.

In comparison to sheet asphalt roads, we saw Argyle road which is entirely of cement concrete. This road was subjected to heavy traffic and yet had stood fairly well. The cost of such a road was Rs. 61/- per hundred square feet.

Again at another place—Chinchbunder road—we saw in progress work of stone-sett pavement laid in cement mortar over 6 inches cement concrete foundation, the cost of which was Rs. 77/- per hundred square feet. It was observed on a bridge nearby, which was provided with a stone-sett pavement, that the surface had worn off very unevenly due to unequal strength of stones. You will agree with me that a careful driver of a motor car would not like to pass over such an uneven road, lest he may damage the springs of his car.

It will, therefore, be interesting to know why the stone-sett pavement was preferred to plain cement concrete road, when the former was costlier and unsatisfactory than the latter.

We were shown very beautiful machinery which I think very few Municipalities in India can boast of It was the first time for me to see a road-heater in action. We saw how the road heater was used in removing the top layer of sheet asphalt in ½-inch depth and we were given to understand that it cost the Corporation Rs. 14/- per 100 square feet Instead of incurring such a heavy expenditure, would it not have been better if ½-inch layer of sheet asphalt was super-imposed over the existing surface. That would not have added much to the camber of the road.

Mr. P. V. Raju (Madras):—We are indeed greatly indebted to the local organising committee for arranging a tour of inspection to the several works, completed and in progress. I need hardly say that we have all profitted considerably by all that we have seen.

I wish first of all to say a few words, in general terms, on the experiments conducted here. I find that, like any other province, Bombay is experimenting a lot in the several types of modernised road surfacings. There is, I am afraid, a lot of duplication of work. I find that in all these matters, where one Province has already conducted experiments and come to certain conclusions, other Provinces have just begin or will begin shortly. My own Province is not above it. We have just laid out several experimental stretches with several types and thicknesses of concrete and bitumen, and we are making observations, while I find that similar experiments have already been carried out in other Provinces and conclusions have been arrived at. It would save a lot of waste if the results of experiments so far conducted in several Provinces could be collaborated and conclusions arrived at thereon, are discussed in this Congress, and, after adoption, passed on to all the Provinces for their benefit. This would avoid the duplication in experiments that are being conducted in the several Provinces individually and result in saving money. No doubt individual members are reading papers on the several experiments conducted and the researches that have been carried out, but it seems to me that the Indian Roads Congress should collaborate all the research work done in India and bring it out in the form of conclusions, so that, much of the repetition that now occurs in the several Provinces might be avoided.

Having had the benefit of attending the International Roads Congress at The Hague, in Holland, in June last year, as a Government of India delegate, may I suggest that the method adopted by that International body may with advantage be adopted by the Indian Roads Congress? The system there is, briefly, this The subjects are sub-divided into main headings, such as: Use of concrete for road surfacing; use of bitumen for road surfacing; sub-grade; traffic control; illumination of roads; slipperiness; administration and finance of road funds; and so on and so forth. A chairman is appointed to each of these committees. The chairman, during the course of the year, issues an exhaustive questionnaire to all the members and subscribing Governments and elicits answers from them. The members and Governments send in their replies, basing them on the experiments conducted or the research work done by them. Their replies are collaborated and the majority opinion is expressed as a draft conclusion on the particular issue for the consideration of the open Congress when it meets next. The draft conclusions are printed and circulated in advance to the members and are discussed and voted upon in the open session before acceptance as definite conclusions by the Congress. These conclusions are then forwarded to the subscribing Governments for adoption by them. This, briefly, is the system followed by the International Roads Congress, and I commend it for the serious consideration of the central organising authorities of this Congress. Perhaps the scope of the technical sub-committee could be enlarged to take up this work

It would be very difficult to draw up standard specifications for all Provinces, but having conducted elaborate experiments in several Provinces in India, it would be easy to arrive at conclusions on the researches conducted from time to time.

Excuse me for this digression. I think that the value of the inspections would be greatly enhanced if we had the draft conclusions of this Congress on each of the items we inspected.

I shall now make one or two observations on the main items we inspected. Taking Bombay, the *Marine Drive*, we find that the number of crossings for the pedestrians along that road are few and far between. One of the members complained that the distances between two crossings were very great, and suggested that there should be crossings at shorter distances. Personally it seems to me that with a road width of 85 feet between kerbs and a central hedge of 5 feet width and with heavy traffic—about 10 motor cars every minute—the usefulness of the Drive would be considerably reduced and the pleasure of the motor drive would be completely lost if crossings were put in at more frequent intervals I would suggest, as an alternative, that sub-ways with steps leading from one pavement to the other might easily be provided.

The same suggestion I make for the pedestrians at the traffic islands. I found that no thought had been given to provide for the crossing of the pedestrian traffic, and it was proving dangerous for the pedestrians to cross from one part of the road to the other, especially when that traffic island was at a place where more than two roads met.

Coming to *Argyle Road*, this is a road made of 1 : 2 : 3 cement concrete and 8 inches thick. I found that it had cracked heavily. It seems to me that the cracks could have been avoided if the thickness of the concrete had been reduced and the mixture had not been made so rich as 1 : 2 : 3. After all, a thick slab of concrete is not required for heavy traffic but only a hard wearing coat. Better results might have been achieved by having a 3-inch concrete slab. But what was more important was an unyielding sub-grade.

The third suggestion I wish to make is about the *Chinchbunder Road*, where stone-setts were being laid on a sand cushion of ½ inch thickness over a cement-concrete foundation, and the joints were being grouted with cement grouting. Would it not have been better if a medium sized road roller had been passed over the setts before cement grouting? It seems to me that the setts would have settled down more firmly and any subsequent subsidence due to loose sand avoided.

These are the few remarks that I wished to make with regard to the roads in Bombay city.

Mr. K. G. Mitchell (President) :—Will Mr. Modak very kindly enlighten us on one point? The very magnificent Marine Drive section which is shown in the notes, (page 42), shows a 2 feet 6 inches storm-water drain approximately under the centre, and yet the camber is outward from the centre in the case of both the carriage-ways. The result of this type of camber is not so important on Marine Drive with a large radius curve; but on Hornby Vellard, for exmaple, the result is that on one carriage-way you get a very considerable camber against traffic when you want banking in favour of the traffic. As the storm-water drain is under the centre—or appears to be—I was rather interested to know why the camber on one side was not converted into banking —and in favour of the traffic instead of against it.

Mr. H. E. Ormerod (Bombay) :—I speak as a layman and not as an Engineer. I would like to make a few remarks in regard to the

necessity for segregating traffic whenever possible, and savings that can be effected thereby if a proper design has been prepared in advance.

In Bombay we have been moving in the matter with the assistance of Mr. Modak through our various Associations, and it is largely due to his co-operation and assistance that we have been able to make considerable progress in a comparatively short period of time.

When the question of the design of the Marine Drive was under discussion, we recommended railings or hedges along the edge of the pavement to prevent pedestrians from stepping off on to the road except at pedestrian crossings. We also advocated the provision of a cycle track. At that time it was considered these suggestions were far in advance of the times, also that the cost might be excessive.

With the help of Mr. Modak, however, we have been able to prove that a properly designed road, with separate tracks for different forms of vehicles, is far cheaper to construct than the old type of road. If you take, for example, a hundred-foot road which is normal for all modern construction in Bombay, and construct the whole of that width with a 6-inch base of concrete and a 3-inch top in asphalt, the cost is much higher than if you design the road so that 5 feet in the middle of the road will be used as a medial strip with 10 feet, for example, at each side for pedestrians and 6 feet, at each side for cycle tracks. The savings which can be effected with such a design are obvious to every Engineer, for there is no sense in providing a 9-inch base of high cost for the use of pedestrians and cyclists. Should you require them, Mr. Modak will, I know, be willing to provide you with interesting figures in this respect.

The bogey of expense, which is usually trotted out when the adoption of something different to the ordinary is suggested, disappears in this case as economies and increased safety for all users of the road can be effected by the adoption of a suitable design.

Mr. N. V. Modak (Bombay):—I shall try to answer all these questions as far as I can. Some questions which have been raised, relate to general policy, and those I shall leave out, because they pertain to matters which have to be decided by the Congress. I shall confine my remarks to questions which pertain to my works.

The first speaker accused us of being extravagant in our use of asphalt, and said that we were wasting the rate-payers' money by constructing asphalt roads on cement concrete foundations when all concrete roads can be constructed at less cost. I can assure him that we do not get our money unless our Corporation is satisfied that what we put forward is an economic proposition in the long run. Our corporators are businessmen! they know what business is, and unless their technical advisers convince them that a particular thing is going to be the best in the long run, they will not agree to give us any money. So, the idea that we are extravagant should be given up entirely. We are working with caution. All our road work is being done with borrowed money and the technical advisers of the Corporation have to convince them that if a concrete road is laid today, it will last 30 years, so that there will be no additional burden during the currency of the loan. I do not think any engineer here has got sufficient experience to say that a concrete road under Bombay conditions can stand for 30 years and that there will be no necessity of

raising another loan during that period. This does not, however, mean that we are against all concrete roads. Since 1930, we have constructed several all-concrete roads. For instance, Hornby Vellard is one of the important roads on which we have used 1 : 2 : 4 concrete. We have, however, taken precautions to fix the levels in such a way that in case the surface goes bad after 5 or 10 years, it may be used as a foundation for an asphalt carpet. It is difficult to renovate a concrete road when it begins to deteriorate.

In the case of city roads, it is important to note, as I pointed out on the last occasion, that the first trouble is the necessity of having to tear up roads for public utility services. As you know, we have to make provision for the laying of underground services such as gas mains, water mains, telephone wires, electricity cables, and so on. At the time of constructing new roads, we ask the public utility companies to co-operate with us by laying the underground services before the road is constructed. In spite of this, we find that one road is completed today and some public utility company comes and tears it up tomorrow. It breaks my heart to see this. But public utility services must be maintained. One company digs a trench at one time, and another comes along and digs another at another time, and that constitutes a source of weakness in the road. That refers to old roads. In the construction of new roads, we can make provision for the different services. You can see how many public utility services we have to provide for.

Moreover, the central part of the city where roads were originally constructed, is growing on modern lines. Formerly a supply of water of 10 to 15 gallons per head per day was considered sufficient, today the rate of supply is over 50 gallons per capita. The water mains and sewers laid in the past are found to be inadequate due to increase in population and consumption of water per capita. This has necessitated the enlarging of the existing water mains and sewers which results in breaking up the road structures. We have also to see that the foundations of our roads do not get scoured. Such are some of the difficulties to be surmounted. We are trying our level best to see that the rate-payers' money is spent to their best advantage by providing all possible amenities demanded by them to suit the modern standard of living.

Some member here referred to cracks which appeared in concrete roads round manholes. To get over this difficulty, the manholes are surrounded with double row of sett stones to facilitate the removal of frame and cover without disturbing the structure of the road.

The question of expansion joints has also been raised and it is asked why expansion joints are being omitted. We started with expansion joints but after seeing their behaviour in some roads we came to the conclusion that they were not necessary, because the variation in temperature in Bombay is not so great and, therefore, no damage is likely to be caused by expansion and contraction. In our new works, we follow the system of laying concrete in alternate bays: we lay the bays alternately, allow them to settle, and then complete the road by laying the intervening bays. We have found that this system has given good results in actual practice.

Now, I come to Mr. Vaswani's suggestions regarding traffic islands, car parks and crossings. Mr. Raju has already replied to those suggestions —as to why there should not be many openings on Marine Drive. We

have at present three crossings. And here I may make it clear that the City Engineer is not the only person who has to deal with the matter. We have got a Traffic Committee. We have to decide what should be done after consultation with them. As Mr. Ormerod has told you, whenever I want to make alteration in a road to regulate traffic a reference is made to the Traffic Committee. It is given effect to after it is considered by that committee. A representation has already been made to the Traffic Advisory Committee suggesting that the existing three crossings are inadequate and additional crossings should be provided. Some members of the Committee are against the proposal of providing more crossings, because they think that it would result in more accidents.

Mr. Vaswani also appears to be under the impression that car parks have been provided in the traffic islands, and that these islands are meant for the children to play in. First of all, I must point out that all these traffic islands that you see were constructed after the roads had been constructed. The roads were constructed many years back, and on account of increased traffic and consequent congestion, we have had to provide these traffic islands. As we have not got sufficiently wide areas at suitable places for conversion into car parks, we thought that, wherever sufficient space was available, these traffic islands were the best places for parking the cars. Moreover, these traffic islands were never intended to be places for children to play in and for people to go to and enjoy themselves. In our new designs of roads all factors such as pedestrian crossings, traffic islands, lighting, and so on, are first thought of. In every work proper foresight is exercised.

Certain questions were raised regarding the embankment, retaining wall and so forth for the Marine Drive. That work is being carried out by the Public Works Department, and the Municipality comes in because the road, after it is constructed, will be handed over to the Municipality for maintenance. According to the Municipal Act, every private owner who constructs a road and wants to hand it over to the Municipality for the purpose of maintenance has to carry out the work to the satisfaction of the Municipality. We say: "You must construct this road in such and such a way, and if you satisfy us that you have done so, we shall take it over for maintenance." Questions as regards the construction of the Marine Drive will, therefore, be replied to by Mr. Daftary, who is the Superintending Engineer in charge of that work.

As regards Argyle Road, Mr. Raju gave reasons as to why cracks developed there. In this connection also, I must say that concrete roads of early days were failures. Nine years back, we again thought of renewing all concrete road construction and Argyle road was the first road to be constructed. Its design and specification were fixed in consultation with the Concrete Association of India and we did our best to see that we adhered to the specifications given by the Association. They at that time suggested that an 8-inch slab with 1 : 2 : 3 cement concrete should be used. In our recent all-concrete road construction we do not consult them—rather we consult them only because we want a rebate! We find that dual control does not result in good and satisfactory work and I think they agree with us. It is much better that one man takes the responsibility and does the work himself.

As regards footpath pavement, the question raised was why we were having three kinds of pavements, blue stone pavement, plain or reinforced

concrete slab pavement and asphalt macadam. This is being done in accordance with the policy laid down by the Corporation in this behalf. At first, the pavements were only of Shahabad stones, but it was found by experience that they got slippery, and we had to spend a lot of money in taking them out. As a result of further investigations the Corporation's present policy is to have three different kinds of pavement to suit different localities according to the user and nature of traffic passing over them. The three kinds of pavement in use have already been mentioned.

I hope I have tried to give explanations on all the points raised. If I have left out any point, I shall be glad to explain it to any member who comes to me.

Mr. R. A. Fitzherbert (Chairman) :—Now we shall take the roads leading out of Bombay.

Rai Sahib Lala Fateh Chand (Bijnor) :—The first point I wish to refer to is about the correction of the camber of the subgrade. In some places, the Public Works Department here has corrected the subgrade by scarifying the old surface up to two or three inches and bringing it to the proper camber. In other places, they have simply picked up the surface and added the required quantity of metal to bring the camber to the required specification. I should like to know the result of both these experiments as regards comparative cost and strength.

Another point is about the use of insulating paper. In the United Provinces, experiments have shown that the use of insulating paper besides being expensive is definitely injurious to the road surface, especially when the thickness of the slab is less than four inches.

The next point is about the use of dowel bars. The depth of the concrete over the hole for dowel bar is hardly 2 inches, and the use of dowel bars at the end, therefore provides the weakest point. I should like to know whether such thick bars as are used are required, if dowel bars are required at all.

Next I come to the gradient. We saw a gradient of 1 in 35, or even, 1 in 30, on some of the asphalt and concrete roads. Is so much gradient required ? Can we not reduce it to 1 in 50 or 1 in 60 ?

The next point is about the width of the concrete road. Where it was only 7 feet, one wheel of the cart often went off the cement concrete road. Would it not be better to have $7\frac{1}{2}$ feet or even 8 feet ?

The last point I wish to refer to is about the use of " Corroid " instead of asphalt. The question is whether the former is stronger than asphalt and cheaper too. The rate is 25 per cent. higher, but the quantity used is only 75 per cent. We have to see whether the strength is the same as that of "Corroid".

Mr. G. B. Vaswani (Karachi) :—In the beginning of the notes on the inspection of roads in Thana Division, you will find mention of different grouts. We were shown in this area roads treated with 3-inch, $2\frac{1}{2}$-inch, 2-inch and $1\frac{1}{2}$-inch grouts and on the Kalwa bridge we saw thick Shalimar tar carpet. The condition of traffic census did not vary much.

We saw that all had stood well and the condition of surface in each case was very good. I wish I could get the same results in my area.

I should like to know on what basis these different grouts are being done. After their experience of a long time, the Public Works Department authorities must have come to some decision on this point.

Mr. P. V. Raju (Madras):—I may be allowed to make a few observations on the roads in Thana Division. I find from a study of the comparative costs per mile of the several types of modernised roads in this Division, that 1½-inch premixed Shalimar carpet, 1½-inch full-grout with asphalt, and 2-inch semi-grout asphalt offer the cheapest types of modernised roads. The other extra thick surfacings were a luxury, because we found the condition of the surfaces practically the same after so much of traffic during several months. In all asphalt-treated roads, to aim at a road surface which will last a very long period seems to me to be a very great mistake. The surface begins to wear out due to emulsification as soon as the viscous oily content of the asphalt evaporates. In a hot climate like India, it is only a question of two or three seasons, after which the surface will require repainting or dressing to replenish the lost oil content. It is the metal that takes the wear and not the asphalt. Asphalt is only a binder, and it requires to be renewed as often as the oily content evaporates from it. Therefore, there is no advantage derived by asphalting to the full depth of the metal. Semi-grout in this respect offers a very economical proposition with surface treatment at intervals of 3, 4 or 5 years.

Mr. G. D. Daftary (Bombay):—I will take first, Mr. Vaswani's question: 'On what basis the various thicknesses of the grouts were made?' You might have already seen from the notes that the work has been spread over almost ten years. We started in 1929 our first concrete asphalt roads. We started with a thickness of 3 inches. In those days it was considered that anything less than 3 inches would not suffice. Eventually, for 3 or 4 years, no work was done as no funds could be spared. When we re-started our work in 1933 we laid down 2½ inches in two layers. As it gave satisfaction, we have adhered to it in regard to both the roads, Bombay-Agra Road and Bombay-Ghodbunder Road, for the past ten years, except in 1937, when a suggestion was made that a section of two miles might be treated with road tar. Road tar has been used near the masonry bridge at Thana, and it has been standing fairly well. A few years ago, when experiments were carried out at Poona, road tar was not found as satisfactory as the present product is claimed to be. That was the only objection. The present tar is slightly different from the tar that we used years ago. The experience near Thana is that the modern Shalimar road tar has stood fairly well. The thickness is 1½ inches. The rate per 100 square feet is Rs. 13. Asphalt for the same thickness would be cheaper. But the modern road tar seems to be working satisfactorily, and it is for the company now to lower their rates for road tar.

Mr. Raju told us that it seemed to him that semi-grout treatment was more suitable. I may tell him that most of our roads, except the first section, are only about four years old, and we have used semi-grout in them. Semi-grout treatment has stood fairly well; it is quite good,

You must have noticed a section while going from Bombay to Kasheli, the section which we extended only last year. We have given semi-grout treatment there. We have repeated semi-grout in our road section just near Kasheli.

As for the Marine Drive, one or two questions were asked by Mr. Vaswani. If you will look into the noltes, you will see that there are three sections of the sea wall. The first section of the wall, 3,800 feet long from the south end of Chowpatty, is the old sea wall. It is a masonry wall, 30 feet high. The reclamation work started somewhere about 1921. Prior to that, the Kennedy Sea Face reclamation was going on, and the sea-wall built was a full masonry wall. It was done for a length of 4 or 5 furlongs. Subsequently, when the Development Department was opened as an independent department, the work was transferred to the Development Department. Section 2 of the wall was done by the Development Department. It is a wall of full concrete raised on a rubble mound. It is about 14 feet high.

A member : Is it cheaper ?.

Mr. G. D. Daftary (Bombay) :—I could not tell you just now. I have no comparative figures. As we proceed from the Charni road end of the wall towards Colaba, good foundations were not available everywhere Pumping out of water was necessary to lay the foundation. Therefore, rubble mound was adopted. The thing had to be done quickly ; it was a question of time. As for cost, I cannot tell you off-hand. A high tiered wall had to be raised. For the remaining length they have a 16 feet wall. The third section is also a concrete wall raised on a rubble mound

Mr. K. G. Mitchell (President) :—One question about the comparative merits of different materials. I understood Mr. Daftary to say that the tar treatment has stood very well, but that relatively it was more expensive. But actually the cost given at page 69 for 1½-inch full-grout asphalt macadam is Rs. 15, whereas the cost given at page 71 for 1½-inch premixed Shalimar carpet is only Rs. 13. That is, of course, one comparison. Supposing the cost of the premix is proportionate to the thickness, then I think that Rs. 13 for 1½ inches compares favourably with the cost given at page 68 of Rs. 23-10-0 for 2½-inch premixed carpet of the other mixture.

Mr. G. D. Daftary (Bombay) : –The rates given there are the rates for the various seasons in which the work was going on The rates I have given are the present rates. Asphalt is cheaper at the present rate. The work treated in the notes has been spread over five years and over. The contractors must have quoted different rates, and the rates quoted in the notes are the rates in the accepted tenders

Mr. R. A. Fitzherbert (Chairman) :—We shall now take the Poona roads. But before anybody asks questions, I should like Mr. Kynnersley to say a few words about the concrete machine.

Mr. T. R. S. Kynnersley (Bombay) :—Before you ask questions, I should like to give a few details about the machine, and then if there is anything more that you wish to know about it, I will endeavour to help you.

To start with, the machine was made by the Pedersaab Company, a very well-known Scandinavian firm of engineers, and was brought out here for the express purpose of helping Government to build expeditiously and well, not only the road now being constructed but also roads in other parts of Bombay Presidency. The machine was ordered to deal with a 10-foot track. That was considered the maximum that we could work so as to leave one side free for traffic. In these semi-jungle roads it is often quite impossible to make a deviation, so that we have to allow traffic on most parts of the road to go alongside when the machine is working. This, you will admit, is a particularly difficult task. If we could deviate the traffic, we could use machines very much more easily. We have to make the best of what we have got.

Subgrade.—The existing water-bound macadam, which has been doing its job for years was scarified and resurfaced with a two-inch layer of the new metal, and in most places where the machine is working, it was consolidated with a 15-ton road roller.

Insulation paper.—The next point is the very vexed question of insulation paper. I have no doubt that if there are 50 members of this congress, 50 different opinions could be expressed on the use of insulation paper. But road paper has come into its own as compared with sand. There may be differences of opinion about this, but it is practically impossible to get to any very definite conclusion because, as you know, scientific investigation of this kind of work is extremely difficult to undertake. There is no doubt whatever that road paper—we call it road paper—is a useful thing; it prevents the water in the concrete getting away. Therefore, engineers can design a mix with the certainty that it goes into the finished road. That is one point. Another point is that the paper, being smooth, allows the road when built to slide backwards and forwards as it wants to. Whether it does as we want it to, is a different point, but it allows it to slide if necessary. The particular paper we used was known as "Vertitas." Its fibre is water-proof. It is obtained in rolls of 100 yards length and 45 inches width. The pre-war rate was 12 annas per 100 square feet or Rs. 8/8/- per roll. The present rate is Rs. 15/- per roll and that works out at Rs. 1/5/6 per 100 square feet. So, as long as the war lasts, we may not be able to use that paper.

Concrete slabs.—Now, we come to the slab itself. The slab is of a uniform thickness of 5 inches. The bay is 35 feet by 10 feet. The total width of the concrete roadway is 20 feet. There are two berms of 2 feet water-bound macadam, one on either side. I shall now give you the proportions. I will not say that it is the proportion that we will always use. The proportion depends on so many things. But the particular proportions that you saw were 1 : 2.33 : 3.9. The coarse aggregate consisted of $66\frac{2}{3}$ per cent of stone broken between $1\frac{1}{2}$-inch to $\frac{3}{4}$-inch, and $33\frac{1}{3}$ per cent between $\frac{3}{4}$-inch to $\frac{1}{4}$-inch. The quantity of water (with machine-tamping) was $4\frac{3}{4}$ gallons to a bag of cement. It is interesting to note that the quantity of water with hand-tamping for 1 : 2 : 4 mix is $5\frac{1}{2}$ to $5\frac{3}{4}$ gallons per bag of cement.

The concrete was screeded to 1 inch above the finished surface. That is a very important point.

The time taken by the machine to complete one bay depends almost entirely on the speed with which you feed it. This is so obvious that

it is hardly necessary to mention it, because it brings home to you that it is not the slightest use buying expensive machines unless you make proper arrangements to feed them. Now, with 3 mixers it will do a bay in 30 minutes; with 4 mixers in 25 minutes; and with 5 mixers in 20 minutes. The ideal theoretical maximum speed is 18 minutes for one bay with 5 mixers. When you went to Poona, you saw 4 mixers working. Now for, 8 working hours per day, the work turned out is: with 4 mixers, 19 bays or practically one furlong; with 5 mixers, it was 24 bays, or approximately 1¼ furlong.

The next point is cost. For the experimental work with the machine, the cost is approximately Rs. 29 per 100 square feet. The cost for the regular work with the machine with 5 mixers is Rs. 24 per 100 square feet. The cost with hand-tamping, as far as thay can get the cost is Rs. 26, You may say from these figures that there is not a great deal in favour of the machines. But I think the actual cost is less than with hand-tamping. I do not want you to go away with any exaggerated ideas about the value of this machine. The truth will come out in due course. But after the experience of the new road I am convinced, and several of those who have had the opportunity of studying it are also convinced, that in laying lengths of roads 50 miles and over, it will definitely be of advantage to have a machine. That is as far as I can go at present. Theie is not a great deal in it, but there is sufficient in it to make it thoroughly well worth investigation.

There is another small point. The engine you saw was consuming 4 gallons of petrol per day—not very much.

Expansion joints:—These expansion joints are difficult, in fact one of the most difficult things for engineers to cope with. You must realise that the tamper which works at 2,500 strokes per minute breaks down the resistence of any flexible material. We tried materials other than ste el, but they were useless. We then tried the steel plate that you saw, and that I believe to be the solution. It is given a slight taper. So as to facilitate withdrawal and is also smeared with grease every time it is used. You may have observed that there were two small holes bored in the steel plate at the outside top corners. In these holes there are small lengths of wire. The coolies get hold of these wires and lift the plate. You saw that the plate was slightly embedded in the road, and many asked me why that was done. The main reason is the advisability of keeping it where it is put. The expansion plates are removed after about 15 or 20 minutes. After the machine has finished the work, before pond-ing, the joints are stuffed with paper to prevent any grit or dirt getting in. Before the road is opened to traffic the joints are filled in with a mastic consisting of 60 per cent Mexphalte R_1, 38 per cent. fine sand and 2 per cent. cement. The mixture was found to be a success. The exact name of the Mexphalte I cannot give you. I think you will get it from the suppliers.

There was a question raised on the use of dowel bars. They were allowed to slide on one side only so as to cope with the expansion and contraction movements of the slab. Now, dowel bars are definitely necessary where you have any doubt as to the resisting power of the foundation. I think you all saw Argyle Road in Bombay. Argyle Road

carries extremely heavy traffic. In Bombay we have a rainfall of something like 72 inches per annum. You can very well visualise that under the pounding action of traffic and with water underneath the ends of the slab, you get a kind of slush formed and every time a 5 or 6-ton lorry goes over the end, you get movement. No concrete will stand repeated bullying of that sort, and ultimately it will collapse. If you carefully watch a five-ton lorry, especially those with solid tyres, (there are very many left in Bombay), going over the joint you will see a definite movement. People call concrete an inelastic material, but it is amazing how elastic good concrete can be, but it cannot go on moving for ever. The dowel bars help the joint by seeing that the soft patch under the ends of the slab is never formed.

If once that patch is formed, you are in for trouble. These dowel bars also assist the ends of the slab to stay quiet instead of acting in cantilever fashion, and take away the rocking action. This saves the bad effect on the subsoil.

I have referred to the question of the use of insulation paper, it is a very contentious point, and I know that Mr. Walker will have interesting things to tell us about the use and non-use of this paper. We shall be very glad to hear them. Nobody wants to spend a single pie per square foot on concrete roads more than we must.

Mr. Syed Arifuddin (Hyderabad-Deccan) :—What is the price of the machine ?

Mr. T. R. S. Kynnersley (Bombay) :—Rs. 11,000. But you should not run away with the idea that Rs. 11,000 is the only cost. You have to add the cost of the steel rails, sleepers etc. I can tell you safely that the machine as it stands working today will cost Rs. 15,000 at pre-war rates.

Mr. J. C. Hardikar (Hyderabad Deccan) :—No doubt the road making machine was doing very quick work. But the important question is whether there is any saving in cost.

The labour employed for mixing, carrying, laying and surfacing concrete was just the same as would be required without the machine, for the same quantity of concrete laid. The machine thus replaces only the labour that would be required for tamping.

If the initial cost, depreciation and working charges of the machine are taken into consideration, it may work out much costlier than hand-tamping.

Actual working data may kindly be supplied.

Nawab Ahsan Yar Jung Bahadur (Hyderabad-Deccan) :—Ultimately, the cost of the machine will be much more than these figures indicate. Probably in these figures depreciation and other things have not been taken into account. The machine is working on petrol. I do not think the figures have been carefully worked out. It is really surprising if the cost is going to be less than hand-tamping. I have been always under the impression that for long stretches of roads, a machine like this would

be economical. What I find at present is that time and labour are wasted by having 4 or 5 mixers. If we had some arrangement whereby a large mixer mounted on rails would be moving with the machine, it might probably effect a saving in wages. In America this system is followed and the mixer is moved along with the machine. If we can get a plant like this, it would really be suitable for long stretches of roads.

Mr. K. G. Mitchell (President):—One or two observations about the mixers. I think that although concrete has been very much improved in recent years, it does want careful supervision to see that a short bag or a bad bag of cement does not go into the mixer. That is a careful business with one mixer. Here we have a considerable number of mixers working at a high pressure to keep the main machine fed and I personally should feel that I could never be quite sure that some mistake had not occurred, unless there were a reliable checker on each mixer.

There is one thing about the dowel bars. I know that the sleeper joint is not advocated, I think, for the simple reason that you merely transfer the danger edge to somewhere else. But in the case of a well consolidated road bed, I suggest that sleeper joints in concrete would be sufficiently water-tight and sufficiently strong, and possibly much less troublesome than the dowel bars.

Mr. G. B. Vaswani (Karachi):—At one place where the work was going on, expansion joint was provided. In another place no joint was provided. Mr. Modak's experience is that expansion joints are not necessary in places like Bombay where variation in the temperature is not high. I should like to have some information on this point.

When we inspected the 'conphalt' roads, we found that the central width of premix was only 9 feet and the width of concrete on sides 7 feet. The Roads Congress has laid down a standard of 10 feet width for a traffic lane. If 7 feet or $7\frac{1}{2}$ feet width is adopted for the sideways and 9 feet for the central portion, then we will have different widths of traffic lanes, contrary to the standard of the Roads Congress. There should be some standard fixed for traffic lanes which should be uniformly adopted by all.

Mr. S. A. Shareef (Hyderabad-Deccan):—I would like to know how the super-elevation on curves is worked out on the roads inspected by us. Theoretically, for a road 30 feet wide on a 500 feet radius curve, the super-elevation for a speed of 40 miles per hour works out to 6.4 feet which is obviously impracticable for slow-moving traffic, animal transport, in particular.

If we treat the super-elevation on road curves as a compromise intended to counteract a portion of the centrifugal force, the balance taking the form of side thrust which is resisted by the lateral friction of the road surface, I would like to know what is the maximum value of the centrifugal ratio to be adopted in the design.

In order to enter and leave the curve without shock, will it not be necessary to have transition curve in place of a circular arc? If so

whether a cubic parabola, a spiral, or a lemniscate is recommended ? It may also be pointed out as to how the maximum super-elevation at the mid-point of curve is graded down to a level and also the minimum grade required to lift the camber, say, from 1 in 60 to a level on either side of the transition curve.

Mr. K. S. Ramamurti (Vizagapatam) :— I have got some doubts. In the case of cross joints in cement concrete, dowel bars were prescribed because cantilever action is said to come into play. In the case of longitudinal joints we give a butt joint. Is it not necessary to have one reinforcing bar on the other side just turning round the cross joint to provide against the same weakness ?

Another point. We have a road of 12 feet width. We want to increase it to 16 feet or 20-feet. In that case we have subgrade on either side. How long are we to wait till one subgrade is consolidated to the same strength as the other subgrade. Is it advisable to lay the cement concrete immediately after doing the subgrades on either side ?

Dewan Bahadur V. G. Shete (Poona) :—I want to get one or two points made clear. On page 53 of the tour notes, we have got a description of the road opposite the race course. In this case you find that 9 feet is the actual width of the asphalt. I was told that 9 feet was the minimum. For roads 23 feet wide, the specification given is 7 feet concrete+9 feet asphalt+7 feet concrete. Is this 7 feet the minimum or the maximum ? We have actually seen longitudinal pushing alongside the same track at the joint of concrete and asphalt; we also saw that repairs were made alongside the same track at this joint. It is very necessary, therefore, that the width of the concrete should be increased to 8 feet, or more—not more than 10 feet. In connection with our visit to Poona, it would have been better if we had seen the city municipal roads. We have got there one road in which separation of up and down traffic has been made. The down traffic coming into Poona is of very heavily loaded carts carrying broken metal and stones. If that road had been done according to the usual specifications laid down, it would have deteriorated very soon. Therefore, they have to give concrete roads. But the finances of the municipality are very poor. Therefore, they struck a mean. One half was designed for carrying heavy loads and made of concrete and the other half was made of asphalt.

The other point is about the construction of the subgrade and the construction of the asphalted portion. When you give a contract you make the contractor responsible for the maintenance of the road for two years. He is made responsible for the asphalted portion only. Is it not better that both the subgrade and the asphalted portion are given to the contractor, so that his responsibility may be properly fixed ?

Another point. You specify a certain proportion for cement concrete, *i.e.*, 1 : 2 : 4. What is actually laid down, are you able to test it ?

Mr. Syed Arifuddin (Hyderabad-Deccan) :—There is one little point that I wanted to ask you about. When examining the joints, we found that a portion of the cement was removed. Would it not be better to put a sort of weight by the side of the iron plate before you remove the plate ? I

do not know whether this idea struck you, and whether it was tried. On both sides of the plate, we put two rails just touching the plate, and then remove the plate so that the mortar is not removed along with the plate, the joints will not break. If this idea has not been tried, I would like to see it tried, and I would like to know whether it proves successful.

Mr. P. V. Raju (Madras):—With regard to the 'conphalt' roads that we saw in Poona, I wish to say a few words about the widths that were adopted. The system of conphalt roads, developed in and around Poona, is a great improvement. It has the advantage of dividing the traffic into traffic lanes, leaving the central strip for fast moving traffic. The ordinary bullock is so sensible that on a road of this type it scrupulously avoids the central asphalted surface and confines itself to the side concreted surfaces which are harder to the wheel and so easier for its traction and cooler to its feet. I would suggest that where new roads are laid, the central asphalted strip be reduced to 8 feet and the side concreted strips be increased to 7 feet 6 inches each, for we find that in actual practice, the 7 feet road that has been adopted, is insufficient. This will give a modernised road of 23 feet in all. In busier places, where it is proposed to provide for two lanes of traffic in asphalted portion, the middle portion may be 15 feet. A central width of 16 to 18 feet seems to me a waste. At all curves, I would suggest that the road be widened from one lane of 8 feet to 2 lanes of 8 feet, that is 16 feet asphalted portion, and where we provide ordinarily two central lanes of traffic, they may be widened to three lanes at all curves. This will go a long way to avoid accidents.

Mr. T. R. S. Kynnersley (Bombay):—I shall endeavour to answer a few of the questions raised. The question of cost was dealt with. My friend Nawab Ahsan Yar Jung Bahadur is a very old hand at this game and I do not propose today to teach him about it. At the same time, I am sure you will agree with me that we are considering the early days of this machinery imported into India for making roads. I think we must be patient about these costs. The results obtained so far, I think you will agree, are satisfactory. I do not for a moment contend that we have reduced the cost as much as we hope to do.

It was pointed out by several members that when you visited Poona you found the road full of coolies moving about in every direction, and the attempts that we have made to organise this business have only resulted in cutting out a certain amount of labour. That does not mean that we have by any means exhausted our resources or inventive imagination, and in due course I think that you will find that these coolies are reduced in numbers very considerably.

One point I have suggested to Government—and I think they are adopting it as quickly as possible—is to have mechanical means to bring cement concrete from the mixers to the machine. One way that is suggested to them is to have little trolleys with grooved wheels running on the existing rails. Those rails have to be there. So why not use them? My suggestion is that we have little trolleys running on the rails taking, let us say, the western rail for the full trip and the eastern rail for the returned empties. The coolies, by means of off-set handles, will trundle these things along and thus save a tremendous amount of labour.

Nawab Ahsan Yar Jung Bahadur (Hyderabad-Deccan):—Something like a mono-rail?

Mr. T. R. S. Kynnersley (Bombay):—It is practically a mono-rail. I think you will find that that will cut out a lot of coolies and useless work. You will be making gravity do some of the things that you do by hand at present. We have to feed the machine as it ought to be fed. The cost would then come down.

The other suggestion was to have the concrete mixer running on rails on a kind of trolley in front of the machine. Then the coolies will have to get the material the sand, the stone and the cement—and put it into the machine which runs on the trolley. Admittedly, the concrete from that mixer will go direct into the place where it is wanted, but there are two points to consider. One is that you still have got the coolies bringing the material to the mixer, and the other is that you have got a very big and cumbersome machine for mixing the concrete. You cannot have it both ways. At the moment you have got 5 small mixers spread out along the road. The proposal is to put one large machine on to the rails. It is possible; I do not say it is not possible. But you have still got to consider that, having brought it, you have got to feed it. You have got to remember that the contractor who is supplying your materials can only do more or less what he is doing today, that is, spread them out along the length of the road, so that, the ultimate amount that is required approximately corresponds with the length of the roadway. I make this point, because the solution does not appear to be so easy. I feel sure that time and experience will solve this problem in the end. Although the difference in cost at the moment is not very great, I think in the end, in 10 years' time, say, we shall find India using many more machines of this type.

With regard to Mr. Mitchell's point about dowel bars, I suppose that most engineers object to dowels. I do not like them. You say you never know whether they are doing their job or not. On the other hand, I do not like—neither does he—expansion joints. But you have had these expansion joints, and you have got to consider them. I do not say that dowels are the last word by any means. But so long as you go on laying concrete in slabs of 35 feet or whatever it is, you have got to do something about it. You cannot, so far as I can see, allow unsupported cantilevers at each end. There was a suggestion made that there should not be cantilevers at all, but that you should bring the ends down on to some sort of solid bed. The Chief Engineer of the Calcutta Improvement Trust made nearly all his roads by bringing the ends of his slabs on to transverse concrete slabs. As Mr. Mitchell very rightly pointed out, you are then really moving your trouble from one place to another. You are putting direct shearing pressure under your concrete at the point where it leaves the slab, so that the situation is not very much eased. In fact, some of the best brains in the world, connected with concrete roads are still fussing over this expansion joint business, and I do believe that the end will ultimately be that we shall tell the concrete that it has jolly well got to take up these strains on its own. In other words the concrete would have to be strong enough to take up internal stresses due to temperature changes. If we can make it do that, I think we shall have gone a long way to solve our problem of concrete roads.

There was the question of longitudinal joints not being properly looked after, and that we spend so much time and trouble over transverse joints. After all, you have got to consider that the longitudinal joint has very little work as compared with the transverse joint. For instance, if you have got two 10 feet tracks for traffic, and if there is a slight movement in between the two, it does not matter. I do not think it is necessary to waste money on material between your longitudinal joints, you should, however, have these joints where they are traversed by the minimum amount of traffic.

There was a remark about the steel expansion plate. It was suggested that when the plate was lifted, there would be a certain amount of concrete adhering to the steel, and it was asked whether it would not be better to put steel angles or something on either side, so as to have a clean joint. My answer to that is that it would be much better to do it, but the expense would be a very serious factor, and I very much doubt whether we can afford to do it, because we have to cut the cost down to the utmost limit. We cannot afford a perfect road. I can show you American catalogues full of the most expensive expansion joints, which undoubtedly do the work. The point is that we cannot afford these at present. We have to do the best that we can with the money that we have got. Those are the main points concerning the machine. The other questions refer to the design of the "conphalt" roads, and Mr. Fitzherbert will deal with them.

Mr. K. S. Ramamurti (Vizagapatam) :—With regard to increase in the width of the sub-grade, suppose it is 10 feet and we want to make the concrete road 18 feet, then we have to add a new subgrade.

Mr. T. R. S. Kynnersley (Bombay) :—It is probably rather unwise to assume that the small amount of added material which we put on preparatory to the making of the concrete has sufficient strength and, in spite of rolling, it is quite obvious that it has not the strength of the original road. Then we are up against practical difficulties again. I entirely agree that it is wrong to expect a newly added thin layer or strip to have the stability of the original roadway. The Government are coping with that as far as they can by using the maximum available width of old road.

Mr. Ramamurti (Vizagapatam) :—Maximum width of the road?

Mr. T. R. S. Kynnersley (Bombay) :—When the width of the ultimate concrete roadway exceeds the width of the old roadway, then it is quite obvious that you cannot go straight on to it. You must do the strip well beforehand and consolidate it. Certainly, in Bombay it would have to have one monsoon over it before concreting. The rains of one monsoon will allow the side berms to consolidate. Otherwise, it is not fair on the concrete or asphalt.

Mr. Ramamurti (Vizagapatam) :—What I meant to say was that there are traffic lanes of 10 feet width.

Mr. T. R. S. Kynnersley (Bombay):—We are adopting a uniform section of 5 to 6 inches instead of having thickened centres and edges.

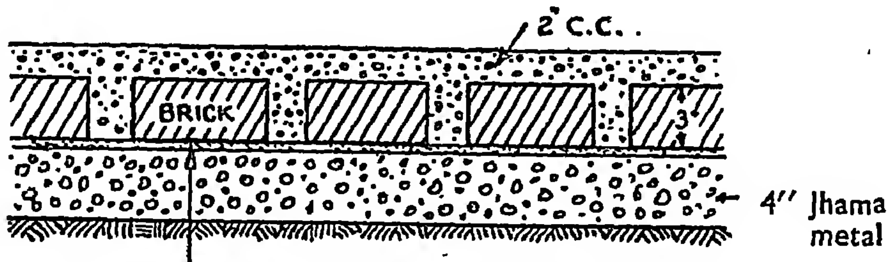
Mr. Ramamurti (Vizagapatam) :—Is any reinforcement required?

Mr. T. R. S. Kynnersley (Bombay) :—No, not as a general rule, even if you suppose that one wheel goes on one side and one wheel goes on the other, or that one heavily loaded wheel goes on the middle of the road. We put a joint in the middle. The reason for doing away with the middle depression is that it is practically impossible to roll the subgrade with a depression. Every road engineer knows that if you try and roll a sub-grade with a depression in the middle you are asking for trouble. Anything less than 5 inches would not do. We consider that 5 inches of concrete is strong enough to take the traffic that is going over this road.

Mr. A. K. Datta (Calcutta) :—I would like to know the cost of providing the dowel joints. We have done a lot of these concrete roads without any dowel joints and they are standing very well. Is it necessary to provide dowel joints where we want cheapness ?

Mr. R. A. Fitzherbert (Chairman) :—That question has already been answered.

Mr. A. K. Datta (Calcutta):—I refer to the point which you are just now discussing and which was raised by Mr. Ramamurti about extension of roads. We had one stretch at the University Road in Lucknow in front of Canning College, where we had 5 inches concrete and also provided 5 inches brick concrete on a new extension. There was no metalled section down below on the part of the new extension. Only 4 inches of road metal (*Jhama* ballast) was laid on the subgrade, and over that was provided 5 inches of bonded brick and concrete (see figure below). That also was meant for heavy cart traffic coming from the brick kilns, and is standing in a very nice condition.



The length that was done with 5 inches concrete is standing as well as the length done with 3 inches brick and 2 inches concrete. We used wet bricks 1½ inches apart.

Mr. W. F. Walker (United Provinces) :—Does the cost allow for the depreciation of the machine ?

Mr. R. A. Fitzherbert (Chairman) :—I agree with Mr. Kynnersley that it is too early to say that machine tamping is going to be more expensive than hand-tamping. We have not had enough experience; we are only experimenting with it.

Another point raised was, why is the concrete in the *'conphalt'* only 7 feet wide ? As a matter of fact, I am afraid it is a mistake in the

notes. It should be 7 feet 6 inches in most cases. One or two years ago Mr. Mitchell was down in Poona and he and I went along that road. We saw the bullock carts going along, and we agreed that $7\frac{1}{2}$ feet was the minimum width ; it might even be 8 feet wide. In the same proportion we put 9 feet at the centre. Some member asked, why not put 8 feet at the centre. We put in 9 feet because the road surface is 24 feet wide.

Dewan Bahadur Shete asked about the 7 feet width. I have answered the question. The chief reason is that there was no time.

Another point was, should not the contractor do both the water-bound macadam of the sub-grade and also the concrete ? That is a matter of administrative opinion. You cannot lay down definitely which is the best.

Dewan Bahadur V. G. Shete (Poona) :—There was a guarantee required from the contractors that they would be liable for the road for two years. One of the conditions in the contract was that the contractor is liable to maintain the asphalt road for two years. That was in Poona, not in Bombay.

* **Mr. Daftary (Bombay)** :—In some of the old tenders that we had accepted in 1937 there was a condition of two years' maintenance. So far as I can remember now, I think the sub-grade was also done by the contractor himself in both cases. There was no separate contractor for the sub-grade. He took the road as it existed, prepared the sub-grade, laid his own premix asphalt surface, and he was responsible for maintaining the road for two years.

Mr. R. A. Fitzherbert (Chairman) :—Then a question was asked as to why the berms are only 2 feet wide on the Bombay-Poona road. That was all that we could get. We had to have a 20 feet width of concrete, with 2 feet on either side, which came to 24 feet. We could not make it wider.

About the use of 'Corroid,' it was used on the bridge you went over, when you saw the concrete work. It was used, but it broke up very badly and rutted. It was not as good as we thought; it was a failure.

* As Mr. Daftary was the Executive Engineer, Poona at the time, he was requested by the Chairman to reply to Dewan Bahadur V. G. Shete's query.

APPENDIX IV

List of Members
(Corrected upto 1.10.1940)

ORDINARY MEMBERS.

Date of election.	Name.	Address.
6.1.1938	Abdul Hai	Assistant Engineer, Asifabad, Hyderabad (Deccan).
22.11.1937	Adke, A. S.	Engineer, District Local Board, Dharwar.
26.5.1937	Adshetti, G. K.	6, Kotak House, Maharashtra Road, Karachi.
3.3.1936	Ahmed, Khairuddin	Executive Engineer, Public Works Department, Hyderabad (Deccan).
27.10.1936	Ahsan Yar Jung Bahadur, Nawab	Retired Chief Engineer, Afsar Manzil, Jubilee Hill, Hyderabad (Deccan).
20.8.1936	Aiyar, C. S. Venkatasubrahmanya	District Board Engineer Trichinopoly.
5.12.1938	Ajwani, H. J.	Assistant Engineer, Khairpur Mir's, Sind.
11.7.1939	Akhtar, S. E.	Assistant Engineer, Ranchi.
10.7.1936	Ali Ahmed	Superintending Engineer, Public Works Department, Shillong.
6.1.1938	Ali, Mirza Mehdi	District Water Works, Hanamkunda (Hyderabad State).
2.12.1936	Ali, Mohamed Vajahat	Assistant Engineer, Public Works Department, Bhongir, District Nalgonda (N. S. Rly.).
2.7.1940	Amingad, A. K.	Sub-Divisional Officer, Public Works Department, Hazurabad, District Karimnagar.
3.2.1939	Amir, S. A.	Executive Engineer, Bhagalpur Division, Bhagalpur, (Bihar).
6.1.1938	Anwarullah	Superintending Engineer, Osmania University Buildings Project, Hyderabad (Deccan).
3.3.1936	Arifuddin, Syed	Chief Engineer, Public Works Department, Hyderabad (Deccan).

Date of election.	Name.	Address.
19.12.1939	Asgar, S. A.	Assistant Engineer, Public Works Department, Hyderabad (Deccan).
5.1.1938	Assudullah, Mohammed	Divisional Engineer, Bhir, (Hyderabad State).
3.3.1936	Ayyangar, Diwan Bahadur N. N.	Retired Chief Engineer of Mysore Basavangudi, Bangalore.
28.9.1936	Ayyangar, M. S. Duraiswami	Chief Engineer, Travancore State Trivandrum.
3.3.1936	Ayyar, K. Rangaswami	State Engineer, Pudukkottai State, Pudukkottai.
3.3.1936	Ayyar, A. Nageswara	Retired Special Engineer for Road Development, 309 Nunmakayalu Street, Tirupathi Madras.
3.3.1936	Ayyar, K. Tirumalaisawami	Superintending Engineer (Communications), Trichinopoly.
24.2.1937	Bagchi, C. C	Municipal Engineer, Lucknow.
5.2 1940	Bahl, M. L.	Executive Engineer, Arrah Division, Arrah.
6.1.1937	Bakshi, J.	Executive Engineer, Bhagalpur.
13 12.1938	Balakrishnayya, P.	Additional District Board Engineer, Vizagapatam.
1.1.1938	Bamji, H. F.	Chief Electrical and Mechanical Engineer, Dawn Mills, Fergusson Road, Bombay 13.
23.10.1939	Bammi, D.R.	Assistant Engineer, Public Works Department, Pali Marwar.
3.3.1936	Banerjee, M. G.	Controller of Stores, Calcutta Corporation, 149, Lower Circular Road, Calcutta.
10.9.1936	Banerji, S. K.	Assistant Engineer, Public Works Department, Bikaner.
3.3.1936	Banerji, Rai Sahib Tulasidas	Assistant Garrison Engineer, Kirkee.
10.1.1939	Bapat, R. S.	State Engineer, Phaltan State, District Satara.

Date of election.	Name.	Address.
15.6.1939	Bansor, H. S.	Sub-Divisional Officer, Military Engineer Services, Happy Valley, Shillong (Assam).
8.9.1937	Barua, H. P.	Executive Engineer, Public Works Department, P.O. Dhubri. (Assam).
5.11.1936	Barua, K.	Assistant Engineer, Public Works Department, Barpeta.
3.3.1936	Bashiram, S.	Superintending Engineer, Roads, Public Works Department, Punjab, Lahore.
5.3.1938	Basu, H. L.	District Engineer, Balasore.
11.12.1939	Batliwala, H. S.	District Engineer, Concrete Association of India, Bombay.
4.3.1939	Bazaz, Sham Lal	Quantity Surveyor, Central Public Works Department, New Delhi.
3.3.1936	Bedekar, K. M.	Executive Engineer, Public Works Department, Karwar.
3.3.1936	Bedekar, V. P.	State Engineer, Miraj Senior (Deccan States).
31.3.1939	Behera, S. S.	State Engineer, Gangpur State, P. O. Sundargarh, *Via* Jharsuguda (B. N. Railway).
23.3.1937	Bennet, C. M.	10, Field Company, C/o Q.V.O. Madras Sappers and Miners, Lucknow.
3.3.1936	Bhaduri, Rai Bahadur S. N.	Chief Engineer, Public Works Department, Gwalior.
17.1.1938	Bhagat, D. G.	Assistant Engineer, C/o Special Road Engineer in Sind, Karachi.
22.6.1936	Bhalla, Prem Nath	District Engineer, Holkar State, Public Works Department, Indore.
3.3.1936	Bhandarkar, G. P., M. B. E.	19, South Tukoganj, Indore (C.I)
23.12.1937	Bhargava, K. N.	Assistant Engineer, (Roads), Alwar.
18.8.1936	Bharucha, M. D.	C/o the All-India Construction Company Limited, Wittet Road, Ballard Estate, Bombay.
3.4.1939	Bhate, K. G.	Assistant Engineer, Public Works Department, Godhra.

Date of election.	Name.	Address.
2.6.1938	Chopra, P. C.	Assistant Engineer, Public Works Department, Wardha, (Central Provinces).
20.1.1937	Chowdhry, S. P.	Assistant Engineer, Kalpalata, Laban, Shillong (Assam).
4.3.1939	Chowdhry, Ram Narain	Assistant Engineer, Public Works Department, Yellow House, Pali, Marwar.
26 6.1940	Chowla, P. D.	Sub-Divisional Officer, Public Works Department, Provincial Division, New Delhi.
20.5.1936	Clayton, Lieut.-Col. R.	Engineer-in-Chief's Branch, Army Headquarters, Simla.
3.12 1938	Cochrane, G. A. D.	Executive Engineer, Akola, (Berar).
10.7.1936	Cocksedge, H. G.	Captain A. I. R. O., 17, Esplanade Mansions, Calcutta.
3.3.1936	Colabawala, Khan Bahadur J. R.	State Engineer, Khairpur Mir's, (Sind).
6.3.1940	Combe, Allan Campbell	General Manager, Messrs. Kumardhubi Engineering Works, Ltd., P. O. Kumardhubi, District Manbhum.
10.7.1936	Cormack, F. E.	Superintending Engineer, Public Works Department, Shillong.
6.1 1938	Daftary, G. D.	Superintending Engineer, Northern Circle, Public Works Department Bombay.
5.2.1938	Dalal, C. C.	C/o The Imperial Bank of India Limited, Hyderabad (Deccan).
13.5.1936	Dam, S. C.	P. A. to the Chief Engineer, Bengal, Communications and Works Department, Calcutta.
14.5.1938	Dangoria, Chaudulal C.	Hughes Town, Murshidabad Road, Hyderabad (Deccan).
10.7.1936	Das, B. C.	Sub-Engineer, Local Board, Tezpur (Assam).
1.10.1938	Das, P. C.	Sub-Divisional Officer, Public Works Department, Cuttack.
22.1.1937	Das Gupta, J. N.	Assistant Engineer, 29, Nicholson Road, Delhi.

Date of election.	Name.	Address.
6.2.1939	Das Gupta, J. N.	27, Lansdowne Terrace, Calcutta.
3.3.1936	Das Gupta, N.	Asphalt Engineer, Standard Vacuum Oil Company, Calcutta.
3.3.1936	Datta, A. K.	Consulting Engineer, 5, Hastings Street, Calcutta.
1.5.1940	Datta, A. K.	Assistant Engineer, Public Works Department, Dumka, Bihar.
10.7.1936	Datta, D C.	Assistant Engineer, Kohima, Naga Hills, Assam.
10.7.1936	Datta, S. K.	Sub-Divisional Officer, Pynursla, Shillong.
3.3.1936	Dave, D. P.	District Engineer, Akola.
10.9 1940	Dayal, B.	Executive Engineer, Champaran Division, P. O. Motihari.
27.4.1937	De, B. C.	Assistant Engineer, Public Works Department, P. O. Sylhet, Assam.
15.1.1937	Dean, A. W. H., M.C., E.D.,	Superintending Engineer, Delhi Province, New Delhi.
7.8.1936	Desai, D. S.	C/o Messrs. Braithwaite & Company (India) Limited, Hide Road, Calcutta.
17.10.1939	Devarajan, A.	Municipal Engineer, Raichur.
3.3.1936	Devasthala, K. B.	District Engineer, Yeotmal, Central Provinces.
3.3.1936	Devi Dayal	Executive, Engineer, Public Works Department, Dibrugarh, (Assam).
20.6.1939	Dhamani, Pessumal Narumal	Assistant Engineer, and P. A. to the State Engineer, Khairpur Mirs', Sind.
25.1.1939	Dhanarajan, S. H.	Municipal Engineer, Trichinopoly (Madras).
29.3.1937	Dhesi, Dilbagh Singh	State Engineer, Sangrur, (Jind State).
6.1.1937	Dighe, V. A.	Chief Engineer, Janjira State, Janjira, (Murud).
18.12.1937	Dildar Hosain	Assistant Chief Engineer, Public Works Department, Saifabad, Hyderabad (Deccan).
1.10.1939	Divatia, S. S.	Executive Engineer, Public Works Department, Larkana (Sind).

Date of election	Name.	Address.
26.5.1938	Doshi, A. G.	*Irrigation Bungalow*, Chenkaladi, Ceylon.
16.2.1937	Doshi, M. M.	C/o The Indian Hume Pipe, Company Limited, Lucknow.
1.12.1937	Dunbar, H. M.	C/o The Concrete Association of India, Victoria House, Calcutta.
3.3.1936	Duraiswamy, M. R.	Municipal Engineer, Tanjore.
3.12.1937	Durrani, N.	District Board Engineer, Nellore (Madras).
18.8.1936	Eccleston, W. T.	Executive Engineer, 4, Civil Lines, Rawalpindi.
4.1.1939	Edgar, S. G.	Superintending Engineer and Public Works Minister, Government of Jodhpur, Jodhpur.
29.10.1936	Edibam, N. R.	Awagarh, Etah, (U.P).
3.3.1936	Edwin, J. W.	Executive Engineer, C. and M. Station Municipality, Bangalore.
3.3.1939	Endlaw, D. N.	Assistant Engineer, 147 A, Hindu Colony, 7, Hari Niwas, Dadar, Bombay.
8.4.1937	Fateh Chand, Rai Sahib	Secretary-Engineer, District Board, Bijnor.
11.8.1937	Fielder, C. J.	C/o Messrs. Turner Morrison and Co., Limited, Calcutta.
3.3.1936	Fitzherbert, R. A.	Superintending Engineer, Central Circle, Poona.
2.12.1938	Fleury, W. R.	Executive Engineer, Sambalpur, Orissa.
21.3.1940	Ganapathy, G. S.	District Board Engineer, Salem.
3.3.1936	Gandhi, Rao Bahadur K. J.	State Engineer, Junagadh, (Kathiawar).
14.6.1939	Ganesan, V.	Engineer, Corporation of Madras, Ripon Buildings, Park Town, Madras.
30.9.1935	Gangadhara, K. S.	Assistant Engineer, Madhugiri (Mysore State).
23.1.1940	Garudachar, B. R.	Superintending Engineer, Mysore Circle, Mysore.
3.3.1936	Ghanekar, Y. K.	Assistant Engineer, Nagpur Improvement Trust, Nagpur.

Date of election.	Name.	Address
13.2.1937	Gharpure, A V.	Supervising Engineer, The Indian Hume Pipe Company Limited, Jamshedpur.
3.3.1936	Ghose, S K	Assistant Engineer, Public Works Department, Chaibasa, (Bihar)
4 8.1936	Gilbert, L. B.	Chief Engineer, Public Works Department, Buildings and Roads Branch, Lucknow (on leave)
26.4.1937	Gilmore, E. F. G.	Director, Industrial Research Bureau, Indian Stores Department, Govt. Test House, Alipore, Calcutta
8 3.1938	Gnanaparakasam, N T.	Local Fund District Board Engineer, Cuddapah
3.3.1936	Goghari, D W.	Retired State Engineer, Bhavnagar.
3.3.1936	Golvala, P. E.	Civil Engineer, C/o Chief Engineer, Bombay Port Trust, Ballard Estate, Fort, Bombay
15.2.1937	Gopal Das	Sub-Divisional Officer, Public Works Department, Rohtak
3 3.1936	Gopalcharya, G	Assistant Engineer, Shermadevi, Tinnevelly District
29.1.1938	Gopalan, M	Special Superintending Engineer, Kachuguda, Hyderabad (Deccan).
3.3.1936	Gough, D. E	Representative of the Society of Motor Manufactures and Traders Limited, 41, Nicol Road, Ballard Estate, Bombay.
15.3.1940	Govel, K C	Assistant Engineer, Special Division No. 1, Central Public Works Department, New Delhi
23.12.1937	Graham, Captain R. C.	R. E. Mess, Aldershot, England
26.6.1940	Grant, C. W.	Executive Engineer, Public Works Department, Provincial Division, New Delhi.
3.3.1936	Griffiths, W. A.	C/o Burmah-Shell Oil Company Limited, Madras
3.3.1936	Gue, Rai Sahib K. C.	District Engineer, Jalpaiguri, (Bengal).
3.3.1936	Gue, T. C.	Chief Engineer, Rewa State.

Date of election	Name.	Address.
26.6 1936	Guha, J. C.	Executive Engineer, Public Works Department, Suburban Division, Calcutta.
24.9.1936	Gupta, Rai Bahadur J. N.	Executive Engineer, Golaghat Division, Jorhat (Assam).
5.4.1936	Gupta, Kanchanendu	District Engineer, Chaibasa, Singhbhum District.
3.3.1936	Gupta, M. C.	Municipal Engineer, 38, Thornhill Road, Allahabad.
23.11.1936	Gupta, S. L.	Municipal Engineer, Delhi Municipality, Delhi.
3.3.1936	Gupta, S. M.	Assistant Engineer, Public Works Department, Bassein, Burma.
20.4.1936	Gupta, T. N.	Ravi Niketan, Gwynne Square South, Lucknow.
12.6.1937	Guru, Ramamurty Pantulu	Supervisor, Vizagapatam Municipality, Vizagapatam.
20.9.1937	Guruswami, S	Assistant Engineer, Howrah Bridge Construction Calcutta.
3.3.1936	Hann, H. W. T.	Managing Director, Braithwaite & Co. (India) Limited, Hide Road, Kidderpore, Calcutta.
12.2.1937	Harmsworth, Major J. R.	Executive Engineer, Canals Division, Peshawar.
23.8.1937	Hall, Captain G. F., C.I.E., M.C.	Chief Engineer, Bihar Public Works Department, Patna.
3.3.1936	Hardikar, J. C.	Executive Engineer, Public Works Department, Warangal. (N.S. Railway).
3.3.1936	Hardit Singh	Executive Engineer, Malakand Division, Malakand.
3.3.1936	Hari Chand, Rai Sahib	District Engineer, Concrete Association of India, 70, Queensway, New Delhi.
24.6.1937	Harris, H. A.	Executive Engineer, 5 Club Road, Lahore.
4.12.1937	Harris, J.	District Board Engineer, Saharanpur.
4.3.1937	Hasany, M. U.	State Engineer, Tonk State, Tonk (Rajputana).
9.5.1940	Hassan, Syed Sarwar	Assistant Engineer, Public Works Department, Mahboobnagar.

Date of election.	Name.	Address.
3.3.1936	Haval, Anant Balwant	Ilaka Panchayat Engineer, Shukhrawar Peth, Kolhapur.
8.12.1937	Hewitt, R. C. L.	Superintending Engineer, Orissa Circle, Cuttack, (on leave).
15.7.1940	Hoda, N.	Assistant Engineer, Public Works Department, Dehri (Bihar).
9.1.1939	Hoey, G. Mc. C.	State Engineer, Jaipur State, (Rajputana).
1.6.1937	Hodgson, E S	Broadway Buildings, Westminister, London
13.3.1936	Hoghshaw, F. H.	Superintending Engineer, Public Works Department, Eastern Circle, Dacca.
3.3.1936	Hughes, H.	18, Park Lane, Rangoon.
25.11.1939	Hukeri, D. A.	Executive Engineer, Shimoga Division, Shimoga (Mysore).
3.3.1936	Ishtiaq Ali	Assistant Municipal Engineer, Delhi.
23.1.1940	Iyengar, C. L.	Supervisor, Public Works Department, T. R S Party, Medak, *via* Hyderabad (Deccan).
15.11.1939	Iyengar, M A. R.	Supervisor, Public Works Department, Gulbarga (Hyderabad State).
3.3.1936	Iyengar, N. Narasimha	Assistant Engineer, 1243, Weaver's Line, Mysore.
2.12.1939	Iyengar, S. V G	Public Works Department, Jagtial, Karimnagar District (N. S Rly.)
25.11.1939	Iyer, B. S. Subrahmanya	Engineer, Messrs. Habeeb Ahmad & Ratanji Kanji, Karimnagar (Camp), (Hyderabad State).
9.12.1938	Iyer, E. V. S.	Executive Engineer, Public Works Department, Koraput, (Orissa).
11.10.1937	Iyer, M. K. Narasimha	Executive Engineer, Ayyanapur, Shimoga District.
3.3.1936	Jagdish Prasad	Assistant to the Consulting Engineer to the Government of India (Roads), New Delhi (on leave).
16.11.1938	Jagmohan	Executive Engineer, 198, Tucker Road, Agra.
3.3.1936	Jardine, A.	Director, Jessop & Company Ltd., 93, Clive Street, Calcutta.

Date of election.	Name.	Address.
16 2.1938	Jayswal, Rai Bahadur U. S.	District Engineer, Muzaffarpur.
3.3.1936	Jivrajani, M. R.	State Engineer, Porbander.
22 4.1937	Jivrajani, P. R.	Assistant Soil Classification Officer, Karachi.
22 4.1938	Joglekar, G. D.	District Local Board, Thana, (Bombay).
16.6.1938	Jones, F. T., C.I.E., M.V.O.	Consulting Engineer to the Government of India (Buildings), New Delhi.
12.1.1939	Jootla, B. S.	Sub-Divisional Officer, Public Works Department, Puri, (Orissa).
3 3.1936	Joshi, Rao Sahib N. S.	Assistant Engineer,, 877, Sadashiv Peth, Poona.
3.2.1939	Joshi, Sitaram Balkrishna	Engineer and Contractor, Examiner Press Building, Dalal Street, Fort, Bombay.
3 3.1936	Joti Prasad	District Engineer, Narsinghpur, (C.I.).
3.3.1936	Jussawala, J. R.	State Engineer, Cambay State.
3.3.1936	Kanhere, V. P.	State Engineer, Bhor State.
1.10.1939	Katarmal, C. L.	State Engineer, Orchha State, Tikamgarh, (C.I.).
16 12.1937	Katrak, M. M.	153, Sappers Lines, Secunderabad.
3 3.1936	Keatinge, H. A.	Executive Engineer, Public Works Department, Rajshahi, Bengal.
3.3.1936	Kelly, R. J.	Assistant Engineer Officer, Civil Aviation Office, New Delhi.
23.12.1937	Keir, J. Oldfield	C/o The Burmah-shell, P. O. Box 84, Karachi.
1.12.1939	Khadeer, M. A.	Divisional Engineer, Special Divisional, Hyderabad (Deccan).
14.10 1939	Khaja Azeemuddin	C/o Dr. Khaja Moinuddin, Opposite Imperial Post Office, Hyderabad (Deccan).
5.1.1939	Khan, Abdul Jabbar	Executive Engineer, Roads, Public Works Department, Rampur State
19 10.1939	Khan, Abdus Samad	Assistant Engineer, Public Works Department, Medak, Hyderabad (Deccan).

Date of election.	Name.	Address.
21.3.1939	Khan, A. R.	Assistant Engineer, Public Works Department, Khairatabad, Hyderabad (Deccan).
15.6.1939	Khan, G H.	Khan Manzil, Nawabazar, Srinagar (Kashmir).
12.1.1938	Khan, K. Md. Nematullah	Divisional Engineer, Nirmal Division, Hyderabad (Deccan).
15.8.1939	Khan, M. A Subhan	Assistant Engineer, Public Works Department, Drainage Secretariat, Hyderabad (Deccan).
16.1.1939	Khan, M. I.	Executive Engineer, Public Works Department, Ganjam Division, Berhampore.
2.11.1939	Khan, Mir Iqbal Ali	Executive Engineer, Public Works Department, Osmanabad, (Hyderabad State).
5.10.1939	Khan, Mirza Mahmood Ahmed	C/o The Hyderabad Construction Company, Limited, Abid Road, Hyderabad (Deccan)
5.1.1938	Khan, Muhamed Abdul Khayyum	Divisional Engineer, Kareemnagar, (Hyderabad State).
30.11.1939	Khan, Nawab Mir Ahmed Ali	Superintending Engineer, Medak, Circle, Medak.
3.3.1936	Khanna, I. N.	Asphalt Road Engineer, Standard Vacuum Oil Co., 9, Babar Road, New Delhi
3.3.1936	Khanna, Prem Nath	District Board Engineer, Muttra.
3.3.1936	Khatri, K. C.	Assistant Engineer, Public Works Department, Jagan Nath Rest House, Abbottabad, Distt. Mardan.
19.9.1936	Kidar Nath, Rai Sahib	Executive Engineer, Public Works Department, Buildings and Roads Branch, Jullundur Cantonment.
20.11 1936	Kikkeri, S. A.	Shalimar Tar Products (1935) Limited, 2/29. Mount Road, Madras.
17.6.1938	Kirk, E. S.	C/o Braithwaite Burn & Jessop Construction Company, Calcutta.
3.3.1936	Korni, Dr. M. A.	Consulting Engineer and Architect, 2, Bishop Lefroy Road, Calcutta.
15.11.1939	Kosnam, S. S.	Assistant Engineer, Public Works Department, Osmanabad, (Hyderabad State).

Date of election.	Name.	Address.
2.9.1940	Kothari, H. J.	Roads Engineer, Burmah-Shell Oil Storage and Distributing Co. of India Limited, Ballard Estate Bombay.
10.8.1940	Kumar, Rai Bahadur S. L.	Assistant Engineer, Public Works Department, Abbottabad.
1.12 1936	Kunte, Vaman J.	City Buildings Engineer, Phaltan State; Phaltan.
13.1.1937	Kuriyan, I.	Retired Engineer to the Corporation of Madras, Ripon Buildings, Park Town, Madras.
13.3.1937	Kutty-Krishnan, O C.	Roads Engineer, The Standard Vacuum Oil Co., Madras.
3 3.1936	Kynnersley, T. R. S.	Chief Engineer, The Concrete Association of India, Esplanade House, Waudby Road, Bombay.
25.11.1939	Lakdawala, Rustom M.	Assistant Engineer, Public Works Department, Jalna, Hyderabad (Deccan).
1.10 1938	Lakshman Swarup	Assistant Engineer, Public Works Department, Dhampur.
26.5.1937	Lakshminarasimhaiya, N.	Executive Engineer, Bangalore.
3 3.1936	Lal, Brij Mohan	Executive Engineer, 52, Jail Road, Lahore.
3 3.1936	Lang-Anderson, Major W. G.	Superintending Engineer, Public Works Department, Bannu.
9.1 1937	Lawson, A. Burns	C/o The Hindusthan Construction Company Limited, Ballard Estate, Bombay.
29.8.1936	Lawley, W.	Superintending Engineer, Bannu.
3.3.1936	Lekh Raj	Civil Engineer, Kapurthala State.
25.3.1937	Lloyd, M. E.	Asphalt Engineer, Standard Vacuum Oil Co., 6, Church Lane, Calcutta.
6.1.1938	Lokendra Bahadur	Executive Engineer, Public Works Department, Raichur.
3.3.1936	Mackenzie, R. H. T.	Chief Engineer, Bikaner State, Bikaner.

Date of election	Name.	Address.
30.8.1940	MacLeod, I.M.	Asphalt Technical Assistant, The Burmah Oil Co. (BURMA TRADING), P. O Box 829 (Dunneedaw), Rangoon
3.3.1936	Madhav, S. K.	Assistant Engineer, Indore City Municipality, Indore
13.6.1936	Mahabir Prasad.	Chief Engineer, Public Works Department, Lucknow.
11.1.1939	Mahapatra, M.	Supervisor, Public Works Department, Bhadrak, District Balasore.
6.1.1939	Malhotra, Ajit Chand	Chief Engineer and Secretary, Public Works Department, Patiala
3.3.1936	Malhotra, Rai Sahib B. R.	Executive Engineer, Public Works Department, Dera Ismail Khan.
5.8.1940	Malik, Jaswant Singh	Executive Engineer, Special Road Division, Hyderabad (Sind)
3.3.1936	Malik, Sardar Bahadur T. S., C.I.E.	Chief Engineer, Central Public Works Department, New Delhi
15.7 1940	Mani, M W. G	District Board Assistant Engineer, Tellicherry
3 3.1936	Manohar Nath	55. Babar Road, New Delhi.
23.11.1939	Manson, J A.S	Executive Engineer, Public Works Department, Thana
23.2 1940	Masudullah, M.	Executive Engineer, Public Works Department, Medak Division, Medak (Hyderabad State).
3 3.1936	Mathew, P. G.	District Board Engineer, Mangalore, South Kanara District.
8.4.1939	Mathur, Kishore Lal	Assistant Executive Engineer, Public Works Department, Jodhpur, (Rajputana).
6.6.1940	Mathur, Rai Bahadur M. S.	Executive Engineer, Special Division No. 1, New Delhi
18.3.1936	McIntosh, R.	Executive Engineer's Bungalow Waltair, Vizagapatam District.
3.3.1936	McKelvie, G. M.	Superintending Engineer, First Circle, New Delhi.
1.5.1936	Meares, C. D. N.	C/o Standard Vacuum Oil Co., P. O. Box No. 1531, Johannesburg.
30.3.1938	Mehra, S. R.	Executive Engineer, III Lahore Provincial Division, Lahore.

Date of election.	Name.	Address.
24.11.1939	Mehta, Des Raj	Executive Engineer, Ranchi Division, Ranchi.
3.3.1936	Mehta, Jagmohandas T.	Town Roads Supervisor, Vadva, (Bhavnagar State)
3.3.1936	Mehta, Iqbal Narain	Municipal Engineer, Multan
22.9.1937	Mehta, N. N	Assistant Engineer, Central Public Works Department, Ajmer (B B. & C. I. Railway).
23.1 1940	Mengi, B. N.	Municipal Engineer, Wazir Bagh, Srinagar (Kashmir).
24.1.1939	Menon, V. K. Aravinda-kasha	Chief Engineer, Cochin Government, Trichur
24.2.1937	Meswani, V. M	Indian Hume Pipe Company, Construction House, Ballard Estate, Bombay.
11 1.1939	Mirza, M A.	Assistant Engineer, Public Works Department, B. & R. Branch, Lucknow
3.3.1936	Mitchell, K G, C.I E	Consulting Engineer, to the Government of India (Roads), New Delhi
3 2.1939	Mitra, Tinkara	Executive Engineer, Darjeeling Division, Darjeeling.
3 3 1936	Modak, N. V	City Engineer, Bombay Municipality, Hornby Road, Fort, Bombay
1 1.1937	Modi, A K	C o The Navsari Electric Supply Company Limited, Navsari
6.1.1938	Mohammad Ibrahim	Executive Engineer, Public Works Department, Asifabad, Hyderabad (Deccan).
16.4.1940	Mohd Ashraf	Assistant Engineer Public Works Department, Yadgir, (G I. P. Rly).
10 7.1940	Mohd. Said	Sub-Divisional Officer, Public Works Department, Dera Ismail Khan.
18.1.1940	Mohd. Ibrahim	Assistant Engineer, Public Works Department, Aurangabad Division, Hyderabad (Deccan).
28.3.1939	Mohomed Usman	Assistant Engineer, Public Works Department, Lingsugur, (Raichur Dist).
3.3.1936	Mookerjee, B: N.	C/o Martin and Company, 12, Mission Row, Calcutta.

Date of election.	Name.	Address.
2.12.1937	Mookerjee, R. N.	8/3, Loudon Street, Calcutta.
2.5.1940	Moorthi, T. S.	Assistant Engineer, Public Works Department, Khammameth, (N. S. Railway).
30.9.1936	Morgan, I.	103, Clive Street, Calcutta.
3.6.1936	Morris, A.E.C.	Branch Manager, McKenzies Limited, Esplanade, Madras.
3.3.1936	Mudaliar, T. Lokanatha	District Board Engineer, 2 Coats Road, Thyagarayanagar.
29.1.1937	Mufti, M. I. D.	A. C. R. E. Works, P. and A. District, Fort William, Calcutta.
20.2.1940	Muhammad Farhatullah	Assistant Engineer, Public Works Department, Deosugur, P. O. Krishna, G. I. P. Railway.
3.3.1936	Mukerjee, Rai Bahadur A. C.	Executive Engineer, Provincial Division, Meerut.
7.1.1937	Mukherji, P. K.	District Board Engineer, Masulipatam, (Kistna District).
4.5.1936	Murari Lal	Assistant Engineer, Gurgaon.
9.6.1936	Murrell, W. L.	Superintending Engineer, North Bihar Circle, Muzaffarpur.
21.1.1939	Murti, N. V. S.	Executive Engineer Bombay.
3.3.1936	Nadirshah, E. A.	Hydraulic Engineer, Bombay Municipality, Fort, Bombay.
5.11.1936	Naidu, R. B. Gobindaswami	Assistant Engineer, Cuddapah, (Madras).
2.12.1939	Najabat Ali	Assistant Engineer, Public Works Department, Nalgonda, (Hyderabad State).
17.1.1938	Nambiar, K. K.	District Board Engineer, Madura.
3.3.1936	Nanda, B. D.	Divisional Engineer, Gilgit Division, Bandapur Palaces (Kashmir).
9.1.1939	Nanda, K. L.	Divisional Engineer, Palaces Division, Srinagar.
16.6.1939	Nangea, Ganpat Rai	Sub-Divisional Officer, Public Works Department, (B. & R.), c/o Postmaster, Pindigheb, District Attock.
9.6.1936	Naqvi, M. H.	Executive Engineer, Public Works Department, Nizamabad, Hyderabad (Deccan).

Date of election.	Name.	Address.
3.3.1936	Narasimham, J. S.	3393, Kingsway, Secunderabad. (Deccan).
5.8.1940	Narayana, A.	Assistant Engineer, Balrampur Estate, Gonda.
19.1.1938	Narayanamurty, B.	Local Fund Assistant Engineer, Nuzvid, Kistna District.
23.11.1936	Narayanaswami, S.	District Board Engineer, Vellore, North Arcot District.
3.3.1936	Nat, Gopal Singh	Civil Engineer, Canal Rest House, Jodhpur, P.O. Sarai Sidhu, District Multan.
7.8.1936	Nath, Raj Mohan	Assistant Engineer Public Works Department, Nowgong, (Assam).
10.7.1936	Nayar, D. P.	Executive Engineer, Provincial Division, Simla.
30.9.1936	Nayar, P. T. Narayana	Special District Board Engineer, Calicut, Malabar.
5.8.1940	Nayyar, Sohan Lal	Sub-Divisional Officer, "A" Provincial Sub-Division, McLeod Road, Lahore.
9 11.1937	Naziruddin, K.	Executive Engineer, Central Division, Patna.
12.1.1940	Nehra, Vidya Sagar	Technical Superintendent, Roads, Public Works Department, Hyderabad (Deccan).
3.3.1936	Newton, B. St. J.	Officiating Chief Engineer, Central Provinces, Nagpur.
5.8.1939	Nicolaides, E. P.	Chief Designer, Messrs. J. C. Gammon Limited, Hamilton House, Bombay.
19.3.1936	Nicolson, J. F. H.	Chief Public Works Officer, Federated Shan States, Taunggyi, Burma.
3.3.1936	Nilsson, D.	Chief Engineer and Director, J. C. Gammon Limited, Hamilton House, Graham Road, Ballard Estate, Bombay.
3.3.1936	Northey, Lt.-Col. H. S.	Superintending Engineer, Public Works Department, P. O. Modigere, Kadur District.
19.3.1936	Nougerede, C. E. de la	Assistant Garrison Engineer, Shillong.
23.11.1939	Nunn, Alfred Henry	Executive Engineer, Chittagong (Bengal).

Date of election.	Name.	Address.
3.3.1936	Oram, A.	Chief Engineer and Secretary to the Government of the N. W. F. P., Public Works Department, Peshawar.
12.2.1240	Padke, Haris Chandra	Local Fund Assistant Engineer, Vizianagaram Sub-Division, Vizagapatam District.
13.1.1937	Pancholi, D. B.	State Engineer, Dhrangadhra State, Dhrangadhra.
18.5.1939	Pancholy, H. M.	Kundan Lal Building, Dharam Peth, Nagpur (C. P.).
3.6.1940	Parang, Hari Ram	Executive Engineer, Public Works Department, Malakand Division, Malakand.
14.3.1936	Parikh, H. B.	Special Road Engineer in Sind, Public Works Department, Karachi-Saddar.
10.1.1938	Parmara, D. S.	A. P. Sen Road, Lucknow.
23.11.1936	Patel, B. D.	Municipal Engineer, Ahmedabad.
3.3.1936	Patel, M. R.	Executive Engineer, Navsari (Baroda State).
1.12.1939	Paterson, H. J.	Executive Engineer, Bombay Central Division, Bombay.
7.11.1939	Patil, G. K.	Executive Engineer, Navsari Division, Navsari.
10.7.1936	Pennell, K. E. L.	Chief Engineer and Secretary to the Government of Assam, Public Works Department, Shillong.
16.1.1940	Phadke, P. G.	Technical Assistant to the Chief Engineer, Holkar State, Indore.
20.1.1937	Pillai, N. P. Sundaram	District Board Engineer, South Arcot Cuddalore, (N.T.).
28.3.1937	Plumley, D. J.	State Engineer, Bastar State, Jagdalpur.
16.5.1939	Prasad, A. P.	Assistant Engineer, No. 3 Sub-Division, Ranchi.
12.2.1940	Pujari, Achyutanand	Executive Engineer, Southern Division, Cuttack.
3.1.1939	Puranik, R. G.	State Engineer, Jamkhandi State, Jamkhandi.

Date of election.	Name.	Address.
25.3.1939	Puri, Dr. A. N.	Physical Chemist, Punjab Irrigation Research Institute, Lahore.
23.1.1939	Puri, B. S.	Executive Engineer, Dehra Dun Central Division, Dehra Dun (U.P.).
11.12.1939	Qureshi, A. H.	Public Works Department Engineer's Residence, Gorakhpur.
3.3.1936	Raghava Acharya V. S. Srinivasa	Retired District Board Engineer, 25 Ranganatham Street, Thyagarayanagar, Madras.
3.3.1936	Raghavachary, K. S.	Assistant to the Consulting Engineer to the Government of India (Roads), New Delhi.
24.11.1936	Rajam, M. K.	Executive Engineer, Buildings Division, Bangalore.
23.7.1936	Raju, P. Venkataramana	Executive Engineer, S. P. Division, Chepauk, Madras.
26.3.1940	Raju, Dr. S. P.	Professor of Hydraulics, Osmania University, Hyderabad (Deccan).
3.3.1936	Ramamurti, K. S.	District Board Engineer, Vizagapatam.
19.7.1937	Ramanujam, M. A.	Executive Engineer, Kadur Division, Chikmagalur, Mysore.
3.3.1937	Ramaswamy, H.	Assistant Engineer, Public Works Department, Bijapur, Bombay Presidency.
1.10.1939	Ramaswamy, K.	District Board, Assistant Engineer, Tirupati, Chittoor District.
8.3.1940	Ramaswamy, K.	Assistant Engineer, Public Works Department, Bhir, Hyderabad (Deccan).
13.8.1940	Ramchandani, J. R.	Assistant Engineer, Public Works Department, Hyderabad (Sind).
8.7.1940	Ramchandani, N. R.	Assistant Engineer, Public Works Department, Karachi Buildings Division, Karachi.
8.11.1939	Ram Sarup	State Engineer, Jind State, Sangrur.
3.3.1936	Rangaswami, V. N.	Road Engineer, Burmah-Shell Co., Madras.
3.3.1936	Rangaswami, V. S.	District Board Engineer, Calicut (Malabar).

Date of election.	Name.	Address.
9.7.1936	Rangaswamy, Rao Sahib M. A.	District Engineer, Darbhanga.
3.3.1936	Rao A. Lakshminarayana	Senior Superintending Engineer and Deputy Chief Engineer, Communications, Chepauk, Madras.
4.2.1939	Rao, B. Krishna	Superintending Engineer, Public Works Department, Shimoga (Mysore State).
3.5.1938	Rao, C. Hanumantha	Divisional Engineer, Parbhani.
21.10.1936	Rao, Ch. Madhava	Local Fund Assistant Engineer, Anantapur.
2.2.1938	Rao, D. V.	Special Officer, i/c Well Sinking Department P. O. Osmanabad, (Hyderabad State).
3.3.1936	Rao, G. Sheshagiri	Executive Engineer, Krishnaraj Sagar, Mysore State.
4.1.1939	Rao, H. Sunder	Assistant Engineer, Dharmapuri, (Salem Dt.)
30.8.1937	Rao, H. R. Sayoji	Assistant Engineer, District Board, Tanjore.
5.9.1936	Rao, K. Subba	Municipal Engineer, Guntur.
3.3.1936	Rao, N. Subha	Chief Engineer, Holkar State, Indore.
19.12.1939	Rao, P. Chander	Pestonji's Bungalow, Seethaphalmandi, Hyderabad (Deccan).
20.6.1938	Rao, R. Sridhar	District Board Assistant Engineer, Gobichattipalayam, Coimbatore District.
24.11.1939	Rao, S. N. Siva	Office of the Cheif Engineer and Secretary to Government, Public Works Department, Hyderabad (Deccan).
19.12.1938	Rao, V. Venkatappa	District Board Engineer, Ganjam, Chatrapur (Orissa).
12.1.1940	Rao, Y. Nageswara	House No. 26, Maradpally, Secunderabad (Deccan).
3.3.1936	Ratnagar, R. D.	Executive Engineer, Public Works Department, Jubbulpore.
3.3.1936	Ray, G. P.	District Engineer, Puri.
16.1.1940	Raza, Syed Ali	Assistant Engineer, Public Works Department, "Astana", Station Road, Hyderabad (Deccan).

Date of election.	Name.	Address.
23.2.1940	Reddy, B. R.	Assistant Engineer, Public Works Department, Raichur.
30.7.1936	Rege, D. Y.	C/o Standard Vacuum Oil Company, Neville House, Ballard Estate, Bombay.
3.3.1936	Rege, S. B.	Executive Engineer, Nasik Division, Nasik.
3.3.1936	Roberts, S. A.	Partner, Bird & Co., Chartered Bank Buildings, Calcutta.
10.7.1936	Romesh Chandra	Executive Engineer, Tezpur, (Assam).
3.3.1936	Rowlands, W. H.	Technical Assistant, Burmah-Shell Oil Company Limited, New Delhi.
6.1.1938	Roy, C. B.	Executive Engineer, Chindwara.
20.1.1939	Roy, J. C.	State Engineer, Public Works Department, Cooch-Behar.
9.5.1940	Roy, S. K.	Chief Engineer and Secretary to Government, Orissa Public Works Department, Cuttack.
3.3.1936	Sadarangani, V. H.	Professor of Civil Engineering, Madras College of Engineering, Saidapet.
15.6.1939	Saha, S. L.	Engineer, Kutubganj, P. O. Mirjanhat, Bhagalpur District.
3.3.1936	Sahgal, Rai Sahib Sant Ram	State Engineer, Mewar State, Udaipur.
3.3.1936	Sahney, J. C.	Assistant Engineer, Public Works Department, Gonda (United Provinces).
3.3.1936	Saksena, C. P.	Assistant Engineer, Public Works Department, Rewa State, 'Sidhi', (B. N. Railway).
1.12.1939	Sandhawalia, Narinder Singh	C/o Shalimar Tar Products Limited, 16, Bank Street, Bombay.
3.3.1936	Sanjana, N. P.	Engineering Assistant, Chief Engineer's Office, Bombay Port Trust, Ballard Estate, Fort, Bombay.
5.1.1937	Sankaram, G. B.	Local Fund Assistant Engineer, Gudivada, Kistna District (Madras Presidency).
19.12.1939	Sarkar, Phani Bhusan	Assistant Engineer, Communications and Works Department (C & B), Kurseong Sub-Division, Kurseong.

Date of election.	Name.	Address.
30.9.1936	Sarabhoja, N.	Chief Engineer, Public Works Department, Bangalore (Mysore).
22.2.1937	Sarkar, R. K.	Retired Municipal Engineer, Nayagaon, Lucknow.
10.11.1936	Satyanarayana, B.	District Board Engineer, Kurnool (Madras).
13.1.1939	Sekharan, T.	District Engineer, District Board, Saidapet.
16.1.1939	Sen, A. K.	Road Engineer, Tripura State, P. O. Agartala.
15.11.1938	Sen-Gupta, L. C.	District Engineer, Rangpur.
23.1.1939	Senapaty, G. N.	Sub-Divisional Officer, Public Works Department, Kendupatna Sub-Division, P. O. Kendupatna, District Cuttack.
3.3.1936	Shah, V. J.	Engineer to Khan Bahadur M. A. K. Mackawee, O. B. E., Government Contractor, Esplanade Road, Camp Aden, Arabia.
29.9.1936	Shahani, C. M.	C/o Braithwaite Burn and Jessop Construction Co., Mercantile Building, Lall Bazar, Calcutta.
3.3.1936	Shannon, Ian A. T.	Burma-Shell Co., Hongkong House, P. O. Box 360, Calcutta.
3.3.1936	Shareef, Safdar Ali	Chief Engineer's Office, Public Works Department, Hyderabad (Deccan).
3.3.1936	Sharma, Hari Shankar	District Board Engineer, Meerut.
4.8.1936	Sharma, S. S.	District Engineer, Almora.
3.3.1936	Shenoy, B. Narasimha	District Board Engineer, Tanjore.
1.10.1939	Shete, Diwan Bahadur V. G.	Retired Consulting Public Health Engineer to the Government of Bombay, 322/2, Sadashiva Peth, Poona.
11.12.1939	Shinde, P. K.	Retired Superintending Engineer, Tarabai Park, Kolhapur.
21.12.1939	Shivaraj, A.	Divisional Engineer, Public Works Department, Aurangabad Division, Aurangabad.
13.3.1936	Shivdasani, K. J.	Chief Officer and Engineer, District Local Board, Larkana, (Sind).

Date of election.	Name.	Address.
5.12.1938	Sinha, A. K.	District Engineer, District Board, Cuttack.
1.7.1939	Sinha, B.	Assistant Engineer, Sub-Division No. 1, Central Division, Patna.
27.11.1936	Sinha, H. P.	Executive Engineer, Central Public Works Department, New Delhi.
1.8.1940	Sinha, M. P.	Assistant Engineer, Dhanbad Sub-Division, Dhanbad.
22.3.1937	Sirajuddin, P.	District Board Engineer, Ootacamund, Nilgiris District (Madras).
3.2.1939	Siri Ram	Chartered Engineer, 10, The Mall, Lahore.
3.3.1936	Smith, Lt.-Col. H. C., O.B.E.	C/o Indian Roads and Transport Development Association, 41, Nicol Road, Ballard Estate, Bombay.
25.7.1938	Sohan Lal	Assistant Engineer, Public Works Department, Balasore, (B. N. Ry.)
3.3.1936	Sondhi, R. L.	Executive Engineer, 27, Race Course Road, Ambala Cantt.
3.3.1936	Sopwith, Colonel G. E.	C/o Messrs. Turner Morrison and Co. Limited, 6, Lyons Range, Calcutta.
3.3.1936	Sowani, D. G.	Consulting Engineer, 89, Girgaon Road, Bombay 4.
3 3.1936	Sri Narain, Rai Bahadur	Executive Engineer, Provincial Division Lucknow
3.3.1936	Srinivasamurti, K. V.	Assistant Engineer, No. 1 Sub-Division, Public Works Deparment, Mysore.
8.11.1937	Srinivasan, K.	Local Fund Assistant Engineer, Tenali.
3.3.1936	Srivastava, Madho Prasad	District Board Engineer, Lucknow.
10.12.1937	Stanier, T. W.	C/o Aveling-Barford Limited, Grantham, England.
3.1.1939	Stein, J. A.	Special Officer, Road Fund Works, Bengal, Calcutta.
3.3.1936	Stevens, Lt.-Col. A. E.	Commanding Royal Engineer, Meerut District Headquarters, Dehra Dun.
5.2.1937	Stuart-Lewis, Allan	District Engineer, Concrete Association of India, Oriental Buildings, The Mall, Lahore.

Date of election.	Name.	Address.
3.3.1936	Subrahmanyam, Ramchandra	Executive Engineer, Madura Municipality, Madura.
3.3.1936	Sujan, S. B.	District Engineer, Concrete Association of India, Wood Street, Karachi.
9.3.1937	Sukhatankar, V. M.	District Engineer, District Local Board, Belgaum.
23.1.1940	Sundaram, S.	56, Straight Mile Road, Jamshedpur.
13.5.1936	Sundaresan, T. V.	Mall Road, Kamptee P. O. Nagpur (C. P.) B. N. Rlailway.
3.3.1936	Sunder Lal, Rai Bahadur	Superintending Engineer, Public Works Department, Nagpur.
3.3.1936	Surati, H. M.	Assistant Engineer, Vallabhdas Estate, Public Garden Road, Hyderabad (Deccan).
9.11.1939	Talvalkar, Vasudev Ramchandra	State Architect and Chief Engineer, Baroda State, Partap Ganj, Baroda.
23.1.1939	Tandy-Green C. W.	Superintending Engineer, Communications and Works Department, Calcutta.
26.1.1940	Tata, Kameswara Rao	Executive Engineer's Office, Public Works Department, Parbhani, (N. S. Railway).
14.3.1936	Todd, J. M.	Executive Engineer, Public Works Department, Pakkoku, (Upper Burma).
3.3.1936	Tonks, H. J.	Executive Engineer, Rangoon Corporation, Rangoon.
23.3.1936	Trevor-Jones, R., M. C.	Chief Engineer and Secretary to Government, Punjab, Public Works Department, Lahore.
24.6.1936	Tripathi, S. N.	Assistant Engineer, Public Works Department, Seoni, (Jubbulpore).
18.5.1937	Trollip, A. S.	General Manager, The Bombay Electric Supply and Tramway Co. Limited, Electric House, Fort, Bombay.
3.3.1936	Turab, Mohamad Abu	Superintending Engineer, Bait-ul-Fazl, Medak (Deccan).
3.3.1936	Turnbull, W. J.	C/o Shalimar Tar Products (1935) Limited, 6, Lyons Range, Calcutta.

Date of election.	Name	Address.
3.3.1936	Tweed, Rathlin J. C.	Works Manager, Braithwaite & Co. (India) Limited, Calcutta.
3.3.1936	Vagh, Balwant Vithal	Road Engineer, Burmah-Shell Oil Distributing Company of India Limited, Bombay.
9.5.1940	Vahidy, Zahir Ahmed	Assistant Engineer, Public Works Department, Etawah (United Provinces).
14.10.1939	Vaidya, G. D.	Engineer, Court of Wards, Station Road, Hyderabad (Deccan).
30.9.1936	Vakil, Rai Sahib N. H.	District Engineer, P. O. Motihari, Champaran.
3.3.1936	Varma, Rai Bahadur A. P.	Chief Engineer, Bikaner State, Sri Ganganagar.
3.3.1936	Varma, R. L.	Executive Engineer, Public Works Department; K. and J. Hills Division, Shillong, (Assam).
14.11.1939	Vartak, G. R.	District Local Board Engineer, Satara City (S. M. C.).
9.2.1940	Vasay, Khaja Mohd.	Assistant Engineer, Public Works Department, Mominabad (Deccan).
3.3.1936	Vaswani, G. B.	Assistant Engineer, Roads, Karachi Municipality, Karachi.
3.3.1936	Venkatakrishnan, Rai Bahadur Lakshminarayana Aiyar	Chief Engineer, Irrigation, Chepauk Madras.
13.3.1936	Vesugar, J.	Superintending Engineer, Public Works Department, Building and Roads Branch, Lahore.
3.3.1939	Vipan, A., C. I. E.	Retired Chief Engineer and Secretary to the Government of Orissa, Public Works Department, Cuttack.
18.7.1938	Viraraghavan, E.	Assistant Engineer, Public Works Department, Wyra, P. O. Khammameth (N. S. Rly.).
3.3.1936	Wadley, K. L. H.	Executive Engineer, Viceregal Estates, New Delhi.
13.9.1937	Wale, N. D.	Engineer, Hubli Municipal Borough, District Dharwar.
18.6.1936	Walker, Brigadier E. C.	The Crutched Friars, Little Whelnetham, Bury St. Edmunds, Suffolk, England.

Date of election.	Name.	Address.
3.3.1936	Walker, W. F., M.C.	Superintending Engineer, Public Works Department, Lucknow.
3.3.1936	Warren, P. F. S.	Director, Jessop & Co. Limited, 93, Clive Street, Calcutta.
29.5.1936	Wellwood, F. D.	Retired Chief Engineer, Mayurbhanj State, Baripade (Eastern States Agency).
1.5.1936	Whishaw, Lt. Col. W.B., O.B.E., M.C.,	Commanding Royal Engineer, Independent Brigade Area, Karachi.
3.3.1936	Whitby, A. B.	Executive Engineer, Lashio East Division, Lashio, N. S. S. Burma.
17.5.1937	Willcocks, H.	Superintending Engineer, Central Public Works Department, New Delhi.
3.3.1936	Winkler, L. A. H.	Superintending Engineer, Public Works Department, Chunnigham Crescent, Bangalore.
10.7.1936	Wooltorton, F. L. D.	Executive Engineer, Shwebo Division Shwebo, Burma.
16.11.1939	Yousuf, M. L. Saberi	Special Engineer, Municipal Corporation, Hyderabad (Deccan).
11.9.1939	Zaman, Chowdhury Imamuz	Sub-Divisional Officer, Public Works Department, Jorhat.
13.9.1937	Zutshi, M. N.	Engineer, District Board, Gorakhpur.

ASSOCIATE MEMBERS.

1.5.1940	Anderson, J. P.	Sales Director, Messrs. Dunlop Rubber Company (India) Limited, Dunlop House, P. O. Box No. 391, Calcutta.
29.2.1936	Chinoy, Nurmahomed M.	C/o The Bombay Garage, Meher Buildings, Chowpatty, Bombay.
27.10.1937	Davidson, J. C. F.	C/o Messrs. Bird & Co. Oriental Buildings, Lahore.
21.2.1938	Ford, T. S.	C/o The General Motors (India) Limited, Bombay.
25.11.1938	Hayward, E.	C/o D. Walie and Co., Konnagar, District Hoogly.
18.3.1936	James, Hugh	Burmah-Shell Oil Storage & Distributing Company of India Limited, New Delhi.

Date of election.	Name.	Address.
29.2.1936	Kerr, W. H.	District Sales Manager for Northern India of Bitumen Emulsions (India) Limited, Lahore Cantt.
2.7.1940	Lumba, H. S.	Chief Civil Engineer & Works Manager, Messrs. Rohtas Industries Limited, Dalmianagar, District Shahabad, (Bihar).
25.11.1939.	Madden, W. J.	C/o Shalimar Tar Products (1935) Limited, P. O. Box No. 194, Bombay.
10.1.1939	Malani, C. T. S.	C/o Messrs. Standard Vacuum Oil Co., Finlay House, Karachi.
29.2.1936	Marschalko, Th. C.	C/o Caltex Company (India) Limited, Bombay.
29.2.1936	Moss, G. L. W.	Technical Service Manager, Dunlop (India) Limited, 39, Free School Street, Calcutta.
25.2.1939	Munday, P.	Arbuthnot Lodge, Shillong.
29.2.1936	Ormerod, H. E.	Esplande House, Waudby Road, Bombay.
27.11.1939	Salter, E .G.	Superintendent of Transport, Travancore State, Trivandrum.
20.9.1936	Smith, J. W.	C/o Standard Vacuum Oil Company, Calcutta.
19.3.1940	Stevens, G.	C/o Anamallai Planters' Association, Sholayar P. O., (Coimbatore Distt).

APPENDIX V.

List of Papers in Annual Proceedings.

Volume I—1934.

1. Objects and Organisation of a Permanent Indian Roads Congress, by K. G. Mitchell, C.I.E., I.S.E.

2. (*a*) Recent Methods used for the Treatment of Roads with Bitumen and Tar in Delhi Province, by A. W. H. Dean, M.C., I.S.E.

   (*b*) The Trend of Development in the United Provinces in the matter of improving Road Surfaces with special reference to recent Experiments, by C. F. Hunter, M. Inst. C.E., A.M.I.E. (India).

3. Earth Road Construction and Maintenance by Machinery, by G. W. D. Breadon.

4. Earth Road Development and Stabilisation with Gravel, by Lieutenant-Colonel A. V. T. Wakley, D.S.O., M.C., R.E.

5. (*a*) Progress made in the use of Tar and Bitumen in the Punjab since the last International Roads Congress in Washington in October 1930, by S. G. Stubbs, O.B.E, I.S.E.

   (*b*) Notes on the Uses of Tar, Bitumens and Emulsions in the Punjab, by R. Trevor-Jones, M.C., A.M. Inst. C.E., I S.E.

6. Asphalt Roads, by G. G. C. Adami, B.A. (Cantab).

7. The Use of Cement Concrete for the Construction of Roads in the Bombay Presidency, by L. E. Greening.

8. Cement Concrete Roads, by W. J. Turnbull, B.Sc., M. Inst. C.E.

9. Concrete Roads in Hyderabad (Deccan), by M.A. Zeman.

10. Corrugation of water-bound macadam road surfaces in the Bombay Presidency and a Cure, by Henry J. M. Cousens.

11. Notes on the Plant Used for Quarrying and Granulating and Operating Costs of the Gauhati-Shillong Road, Khasi and Jaintia Hills Division, Assam, by B. F. Taylor, V.D.

12. Some Physical Aspects of Roads and Tyres, by G. L. W. Moss.

13. Test-Tracks—A Suggestion, by C. D. N. Meares.

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14. An Analysis of Delhi Road Traffic Census, by R. L. Sondhi, I.S.E.

15. A study of the Relationship between Vehicular Traffic and Road Surfaces as affecting the selection of an Economic Road Surface, by H. P. Sinha, I.S.E., and A. M. Abbasi.

16. Traffic Census and Road Diagrams, by Lieutenant-Colonel W. de H. Haig, D.S.O.

17. Economics of Road Maintenance, by S. Bashiram, I.S.E.

18. Necessity for Surface Treatment of Important Tourist lines and some aspects of Economical Work in that direction, by V. S. Srinivasaraghava Achariar.

19. Treatment with Molasses of the Bangalore-Mysore Road, by Diwan Bahadur N. N. Ayyangar, B.A., L.C.E., M.I.E. (India), I.S.E.

20. The Road Problem in India with some Suggestions, by Colonel G. E. Sopwith.

21. General Review of the Results of Recent Road Experiments in India as revealed by Modern Practice, by K. G. Mitchell, C.I E., I.S.E.

22. Road Research and Results, by C. D. N. Meares.

23. (*a*) Roads in Rural Areas (Village Roads), by Honorary Captain Rao Bahadur Choudhry Lal Chand, O.B.E., M.L.A.

    (*b*) Gravel Roads, by Diwan Bahadur N. N. Ayyangar, B.A., L.C.E., M I.E (India), I.S.E.

    (*c*) Vitrified Bricks for Surfacing Roads in Deltaic Districts, by G. Gopala Acharya.

24. Oil as a Binder for Earth and Gravel Roads, by T. G. F. Hemsworth, B.A., B.A.I., I.S.E.

25. Cement-bound Roads, W. J. Turnbull, B.Sc., M. Inst. C.E.

26. The Necessity for a Reasonably Uniform Standard Loading for Design of Concrete Bridges and a Suitable Loading for Such and Other Types of Bridges on Highways in India, by M. G. Banerji, B.A., B.E., A.M. Inst. M. and Cy. E., M.A.E., F.Sc.

27. Design of highway bridges. The necessity for an All-India Specification, by W. A. Radice, B.A., A.M.I.C.E., G. Wilson, B.Sc., A.M.I.C.E. and P. F. S. Warren, B.A., A.M.I.C.E.

28. Permissible Stresses in Concrete Bridge Design, by W. J. Turnbull, B.Sc., M. Inst. C.E.

29. Regulation and Control of Motor Transport in Mysore, by H. Rangachar, M.A.

30. The Construction of the Shillong-Jaintiapur Road in the Khasi Hills, Assam, by F. E. Cormack, I.S.E.

31. A Method of Rapid Road Reconnaissance, by Captain (now Major) W. G. Lang-Anderson, R.E.

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32. Some Notes on the layout of Rural and Suburban Roads in the Punjab, by R. Trevor-Jones, M.C., A.M. Inst. C.E., I.S.E.

33. Roads and Public Health in India with special reference to Malaria, borrow pits, and road dust, by Raja Ram, B.Sc., A.M. Inst. C.E., F.R. San. I., M.I.E. (India).

34. Further Notes on treatment of Roads with Bitumen and Tar in Delhi Province, by A. W. H. Dean, M.C., I.S.E.

35. Economy and Developments of Bonded Brick Concrete Roads, Plain and Reinforced, by A. K. Datta, B.E., M.I.E. (India), M.A.E.

36. Ways and Means of Improving the Bullock-Cart, by G. L. W. Moss.

37. Indian "Road-Aggregates", Their Uses and Testing, by R. L. Sondhi, I.S.E.

38. Submersible Bridge across Parbati River at Mile 231, Agra-Bombay Road, by Rai Bahadur S. N. Bhaduri, B.A., C.E., M.I.E. (India).

39. Optimum Weight of Vehicles on extra municipal Roads, by K. G. Mitchell, C.I.E., I.S.E.

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A. (*i*) A Method of Calculating the Stability of Braced Pile Piers, by Guthlac Wilson, B.Sc., A.M.I.C.E., A.M. Am. Soc. C.E.

(*ii*) The Dhakuria Lake Bridge, by Guthlac Wilson, B.Sc., A.M.I.C.E., A.M.I.C.E., M.I.E. (India).

B. Franki Pile Foundations for Road Bridges, by W. A. Radice, B.A., A.M.I.C.E.

C. Reinforced Cement Concrete Bridges of 24 feet span constructed in Gwalior State, by Rai Bahadur S. N. Bhaduri, B.A., C.E., M.I.E. (India).

D. Reinforced Concrete Bridge across the Godavari River at Shahgadh in Hyderabad State, by Dildar Hosain, B.E., M.I.E. (India).

E. Safe Wheel Loads for Indian Roads, by K. G. Mitchell, C.I.E. I.S.E., and Jagdish Prasad, C.E.

F. Roads under Local Bodies and how to Maintain them, by Rai Sahib Fateh Chand.

G. Corrugations on Road Surfaces, by G. B. E. Truscott.

H. An Aspect of Traffic Statistics, by Ian. A. T. Shannon.

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J. Design of Reinforced Concrete Bridges of Short Spans for Indian Roads, by Brij Mohan Lal, I.S.E.

K. (*i*) Collection of Material for and Consolidation of Waterbound Macadam, by R. Trevor Jones, M.C., M. Inst. C.E., I.S.E.

(*ii*) Layout of Roads, by R. Trevor Jones, M.C., M. Inst. C.E., I.S.E.

L. Some Aspects of Bituminous Road Construction in India, by Colonel G. E. Sopwith, M.C., and W. A. Griffiths.

M. Ribbon Development, by A. S. Trollip.

N. Soils in Relation to Roads, A Bibliological Study, by G. W. D. Breadon.

O. The Use of Soil Stabilization in Unmetalled and Metalled Roads in India, by Sita Ram Mehra, Assoc. M. Inst. C. E.

P. Revitalization of Tarred or Bitumened Surfaces by Mix-in-Place Methods using Cut-Back Asphalt, by Captain R. C. Graham, R.E.

Q. Surface Treatment of Concrete Roads when Outworn, by W. A. Radice, V.D., B.A. (Cantab), A.M. Inst. C.E., M. Inst. I.E.

R. A Serious Failure in the Painting of a Steel Highway Bridge, by W. L. Murrell, B.C.E. (Melb.), A.M. Inst. C.E., I.S.E.

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A—39. Evolution of the Thin Concrete Road in the United Provinces, by W. F. Walker, M.C., I.S.E.

B—39. Repair and Maintenance of Cement Concrete Roads, by Rai Bahadur A. C. Mukerjee, I.S.E.

C—39. Development and Application of Village Cement and High Silica Portland Cement for the Construction of Concrete Roads, by A. K. Datta, M.I.E. (India).

D—39. The Sai Bridge, by Dr. M. A. Korni, M.I.E. (India).

E—39. Present Day Methods of Bituminous Road surfacing work in Chota Nagpur, Bihar, by S. A. Amir, I.S E.

F—39. Stabilization of the Unmetalled Berms of Metalled Roads, by S. R. Mehra, A.M. Inst. C.E.

G—39. Light Bituminous Surfacings, by Ian A. T. Shannon and B. V. Vagh.

H—39. An Economical Substitute for Waterbound Macadam, by A. Lakshminarayana Rao.

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J—39. Roads in India and Australia—Our difficulties and some Suggestions, by W. L. Murrell, I.S.E., A.M. Inst. C.E.

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